Separating Local and Cosmic Soft X-Ray Emission in the Chandra Deep Field-South: A Preliminary Report

Brad Wargelin

Chandra X-Ray Center

Smithsonian Astrophysical Observatory

The Local Origin X-rays (LOX) Collaboration

- Greg Brown (LLNL)
- Tom Cravens (U. Kansas)
- Alex Dalgarno (CfA)
- Dick Edgar (CfA)
- Mike Juda (CfA)
- Vasili Kharchenko (CfA)
- Paul Plucinsky (CfA)
- John Raymond (CfA)
- Ina Robertson (U. Kansas)
- Jon Slavin (CfA)
- Randall Smith (CfA)
- Brad Wargelin (CfA)

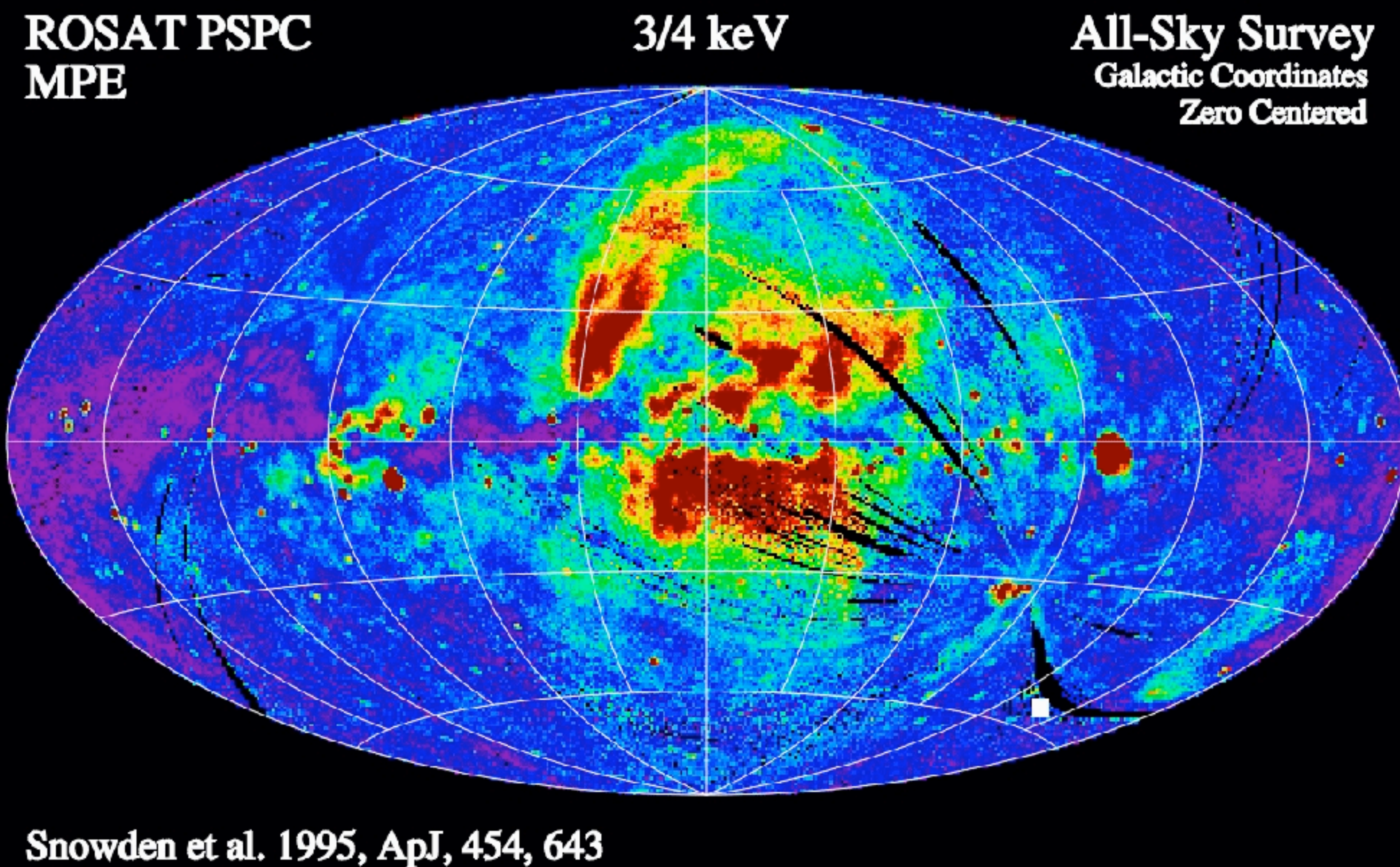
The Soft X-Ray Background (SXRB)

SXRB emission components:

- Absorbed extragalactic (~power law)
- Absorbed thermal Galactic Halo emission
- *Unabsorbed thermal from Local Bubble*
- *Heliospheric and geocoronal solar-wind charge exchange (CX)*

How much emission is from the Local Bubble vs CX?

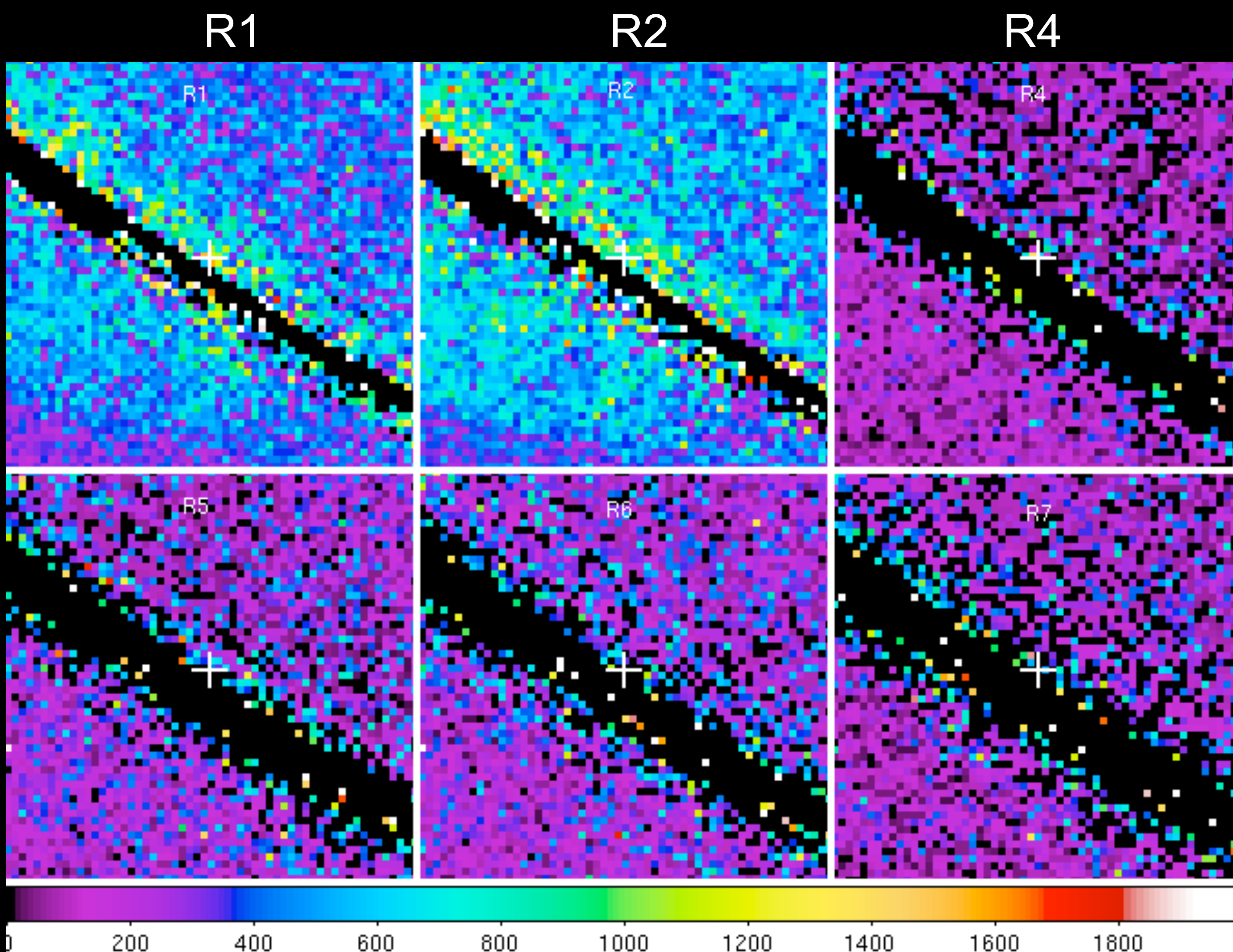
What can the Chandra Deep Field-South data tell us about this in the 3/4-keV band?



RASS conducted at solar maximum.

LTE

contam?

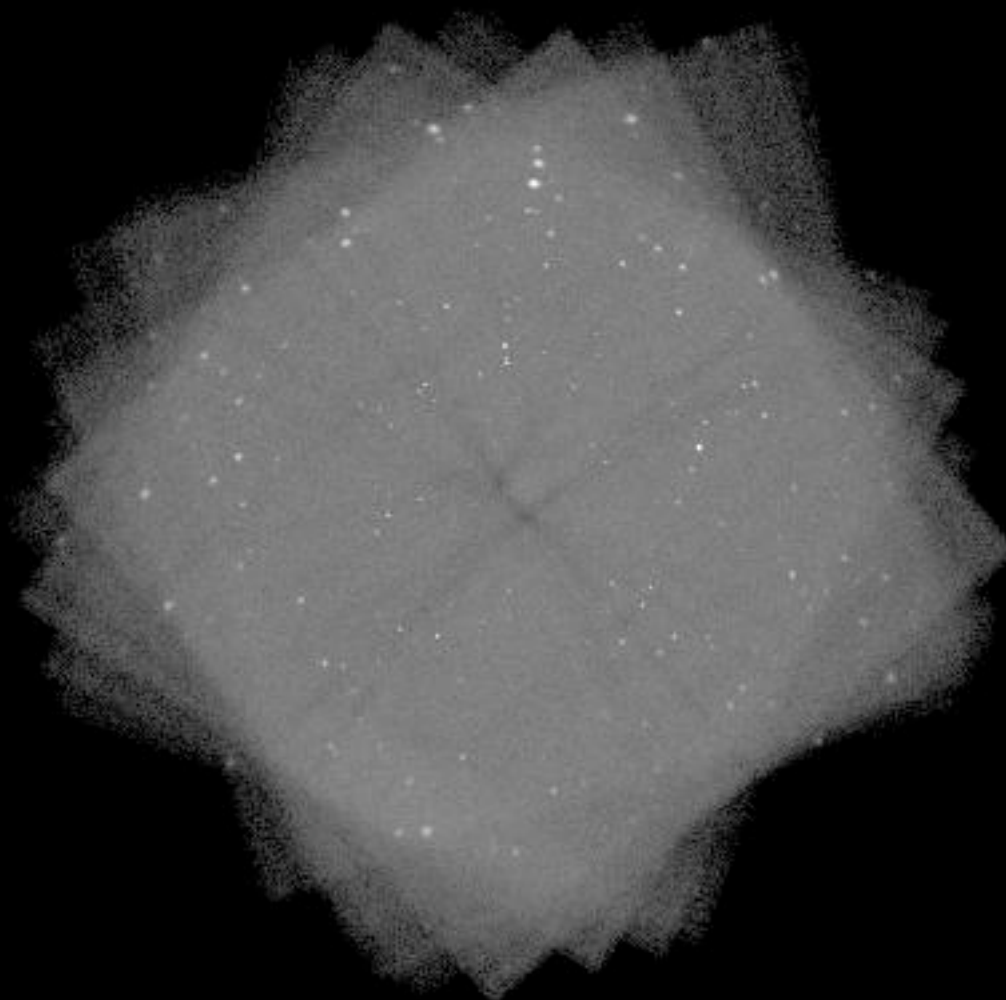


M. Juda

The CDFS

The CDFS observations:

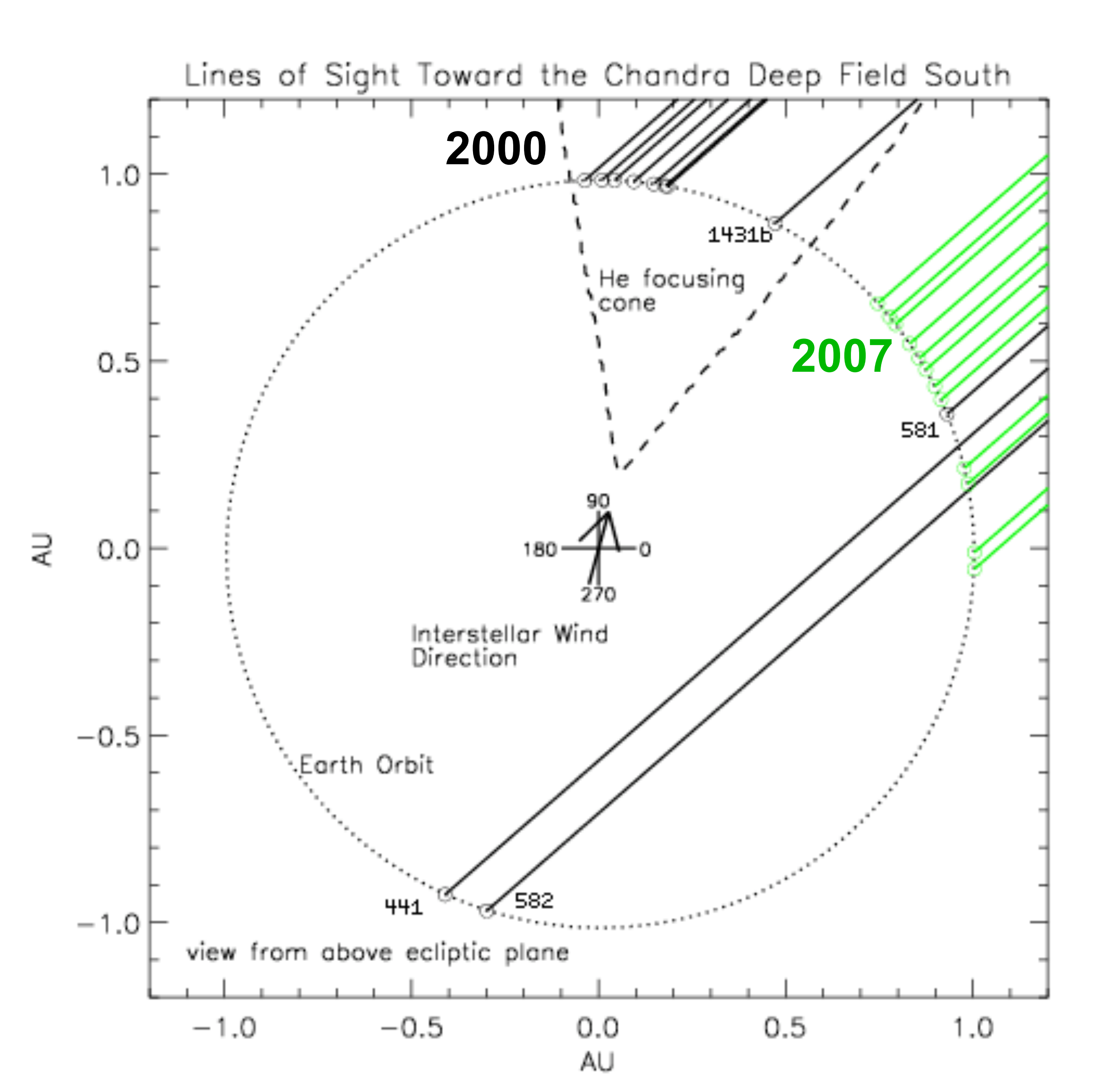
- 3 in Oct, Nov 1999 (-110 C)
- 9 in May, Jun, Dec 2000
- 12 in Sep-Nov 2007 (VF mode)



RA,Dec	3:32:28, -27:48:30
Gal l,b	223.6, -54.4
Ecl lat,lon	41.1, -45.2

836 ks in 2000 (most from within He focusing cone, near solar max)

981 ks in 2007 (outside He cone, at solar min)



LOS is 45° down, into page.

Because of solar wind charge exchange, the observed SXRB depends on:

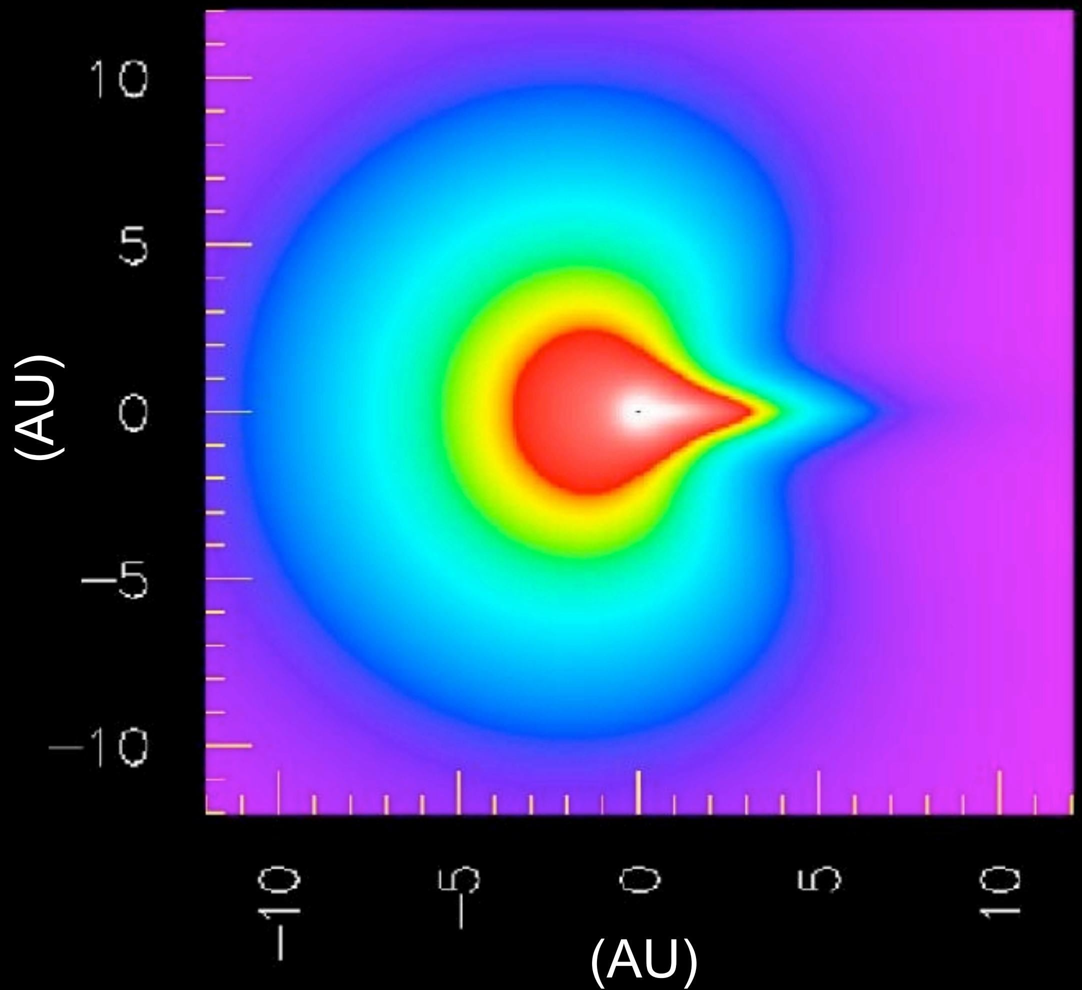
•Where you look

•Where you look *from*

•When you look

J. Slavin

CX Emission--looking down on ecliptic plane

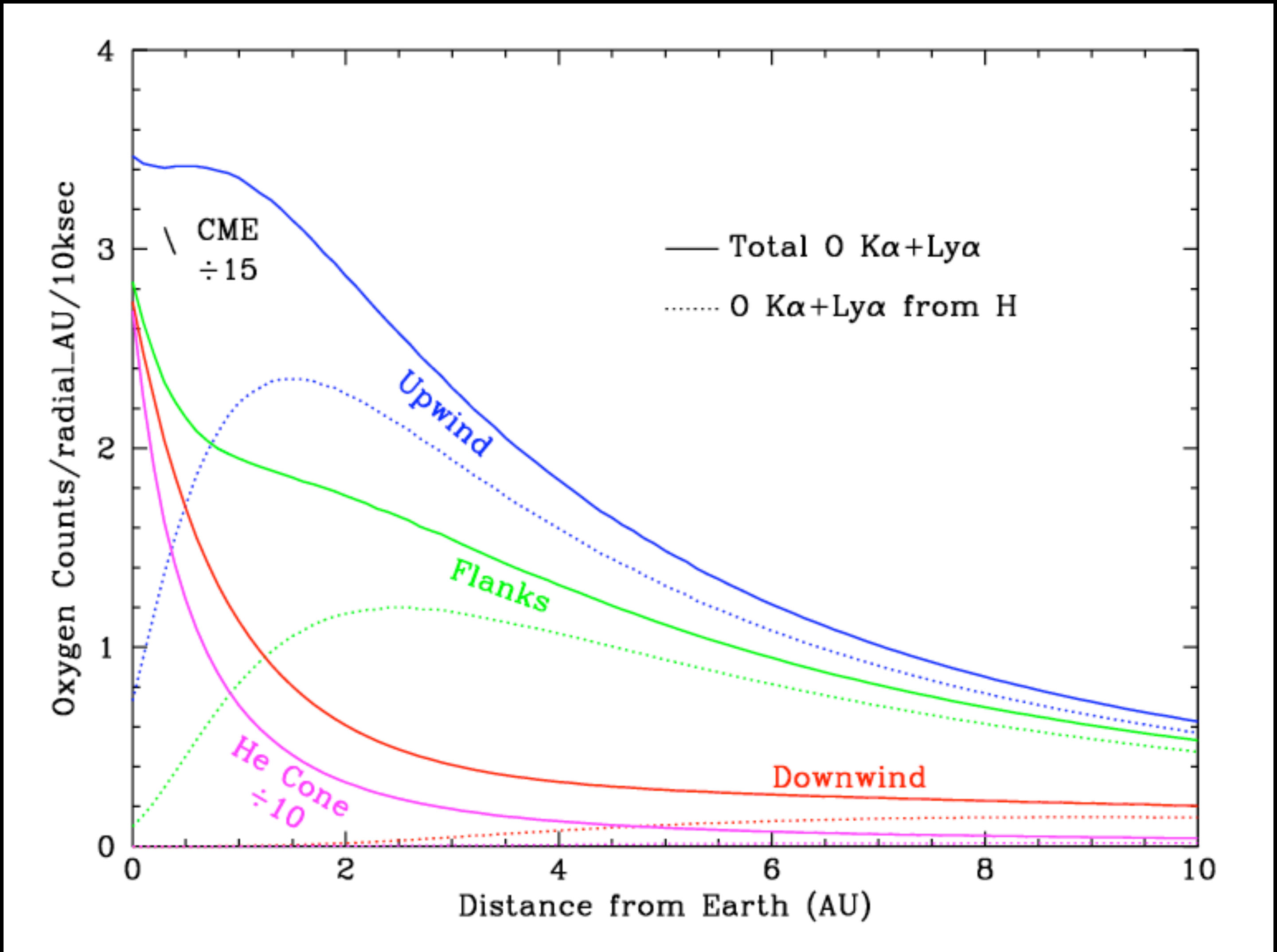


More neutral H upwind

He focussing cone downwind

Pepino et al., ApJ 2004

Where does the observed SWCX emission originate?

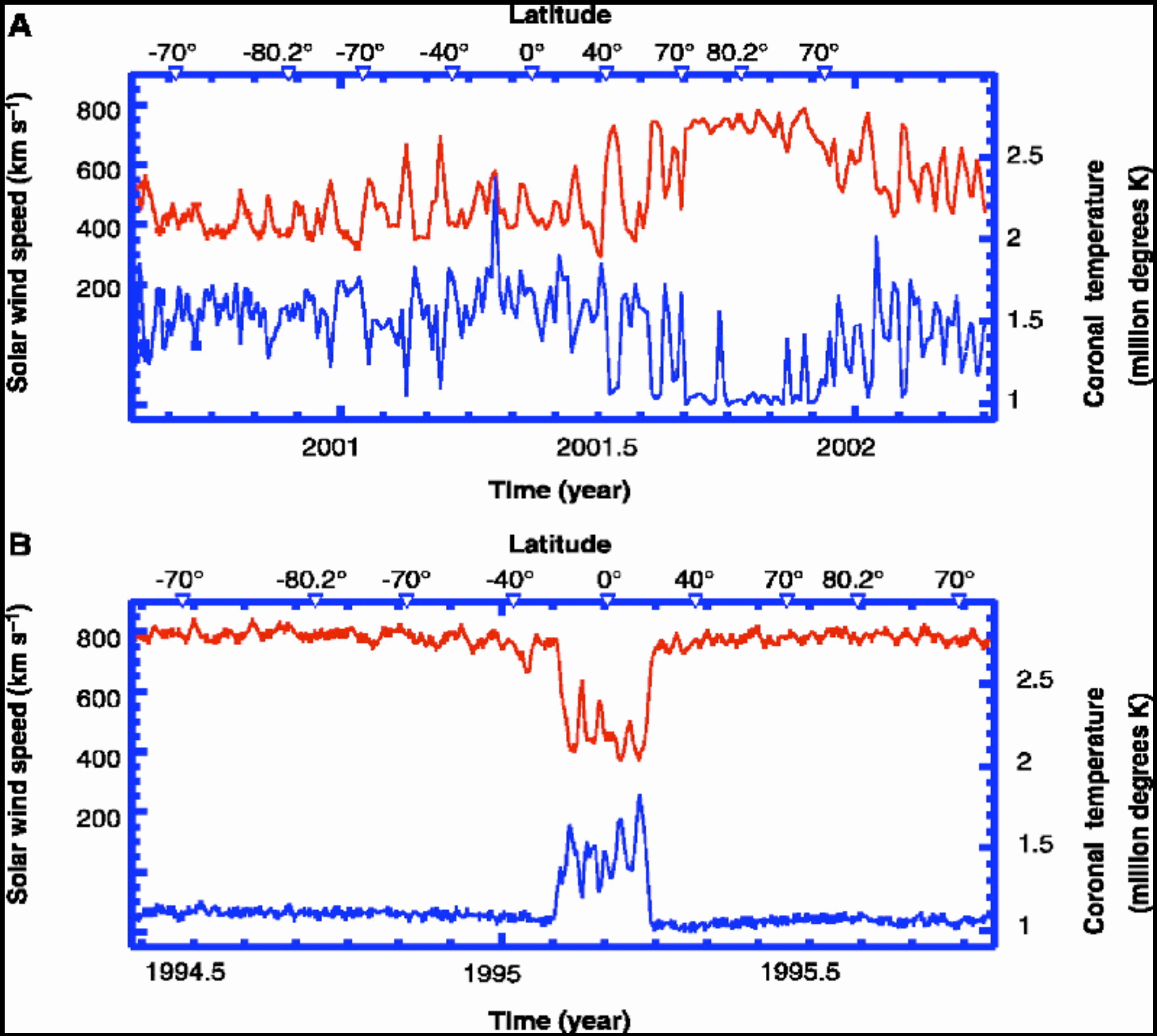


From within the He cone, CX intensity is higher *and* more of the emission comes from nearby, where SW conditions can be measured.

Solar Max vs Solar Min

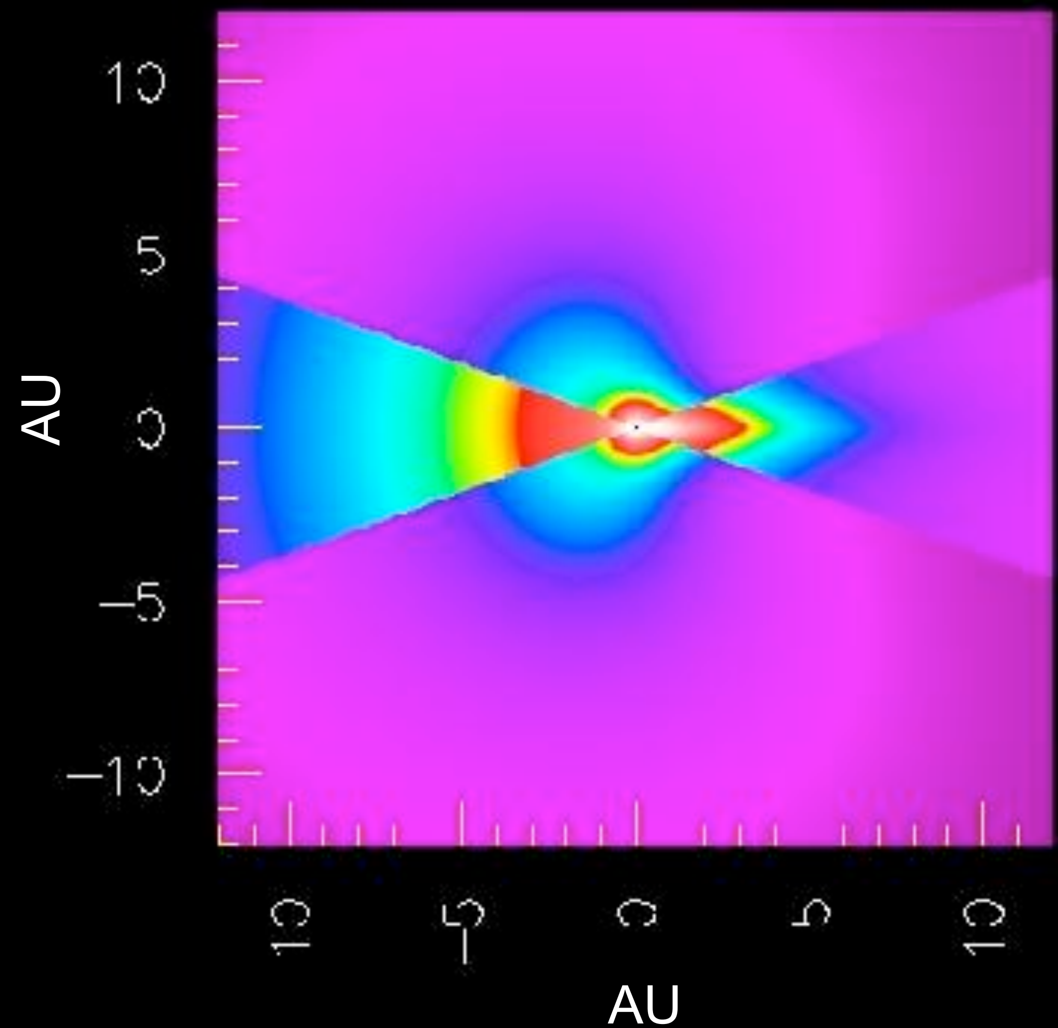
At solar max, wind is a mix of slow and fast at ~all latitudes.

At solar min, wind is stratified, with slow between latitude -20° and +20°.



Ulysses data --E.J. Smith et al., Science 2003

CX Emission at Solar Min--view from Ecliptic Plane

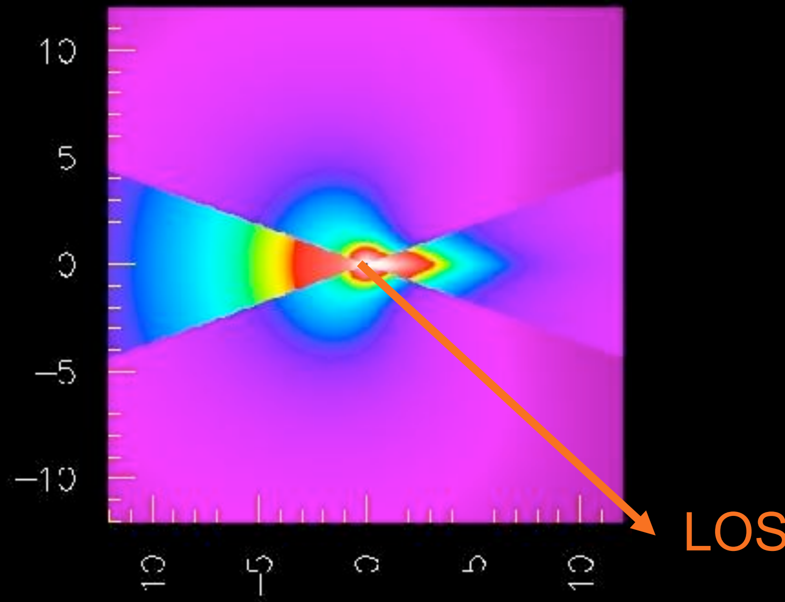


Stratified wind--slow and highly ionized near ecliptic $\Rightarrow$ higher CX emissivity.

Little emission in fast wind.

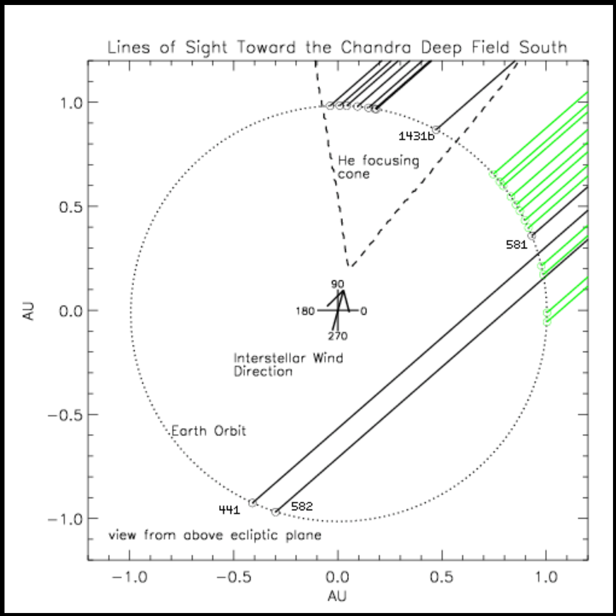
Pepino et al., ApJ 2004

- In 2000, there is slow wind all along the LOS and most obs's are from within the bright He cone.
- In 2007, SW is stratified, LOS through fast wind, obs's outside He cone.



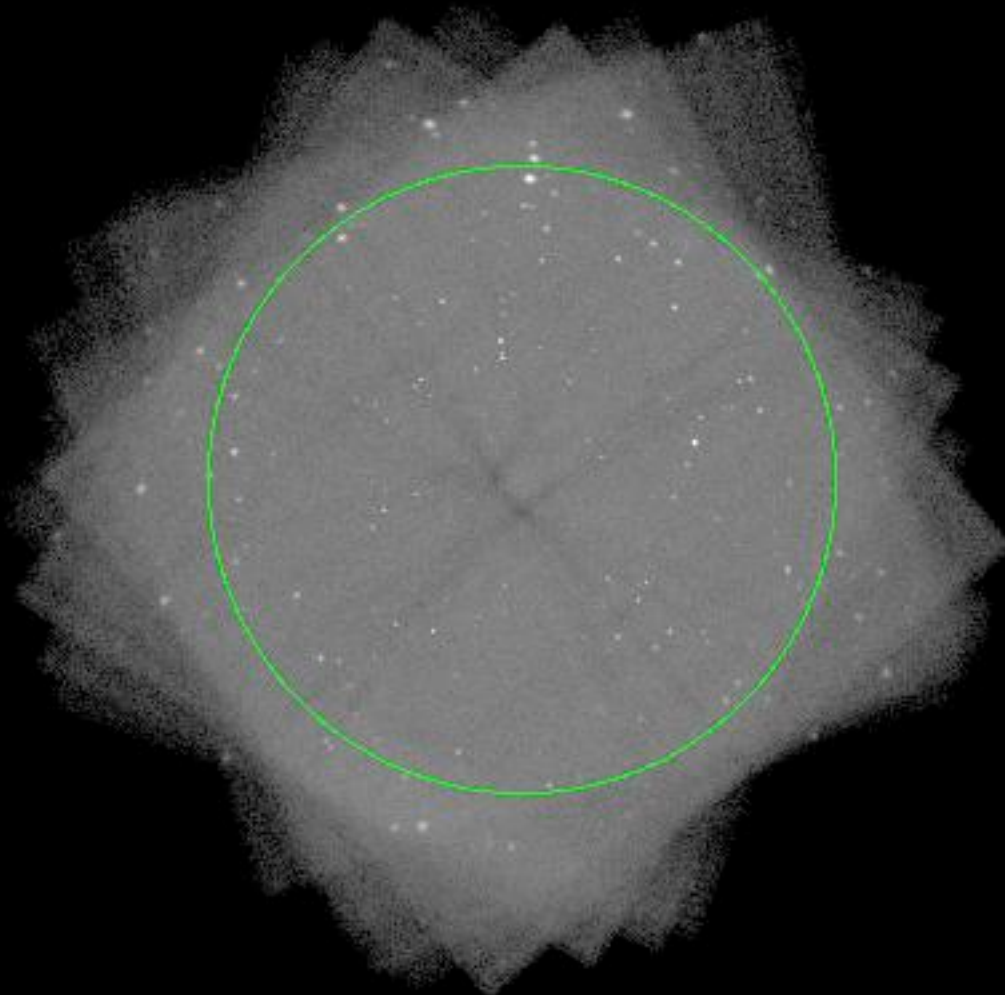
Expectations for 2000 vs 2007 data:

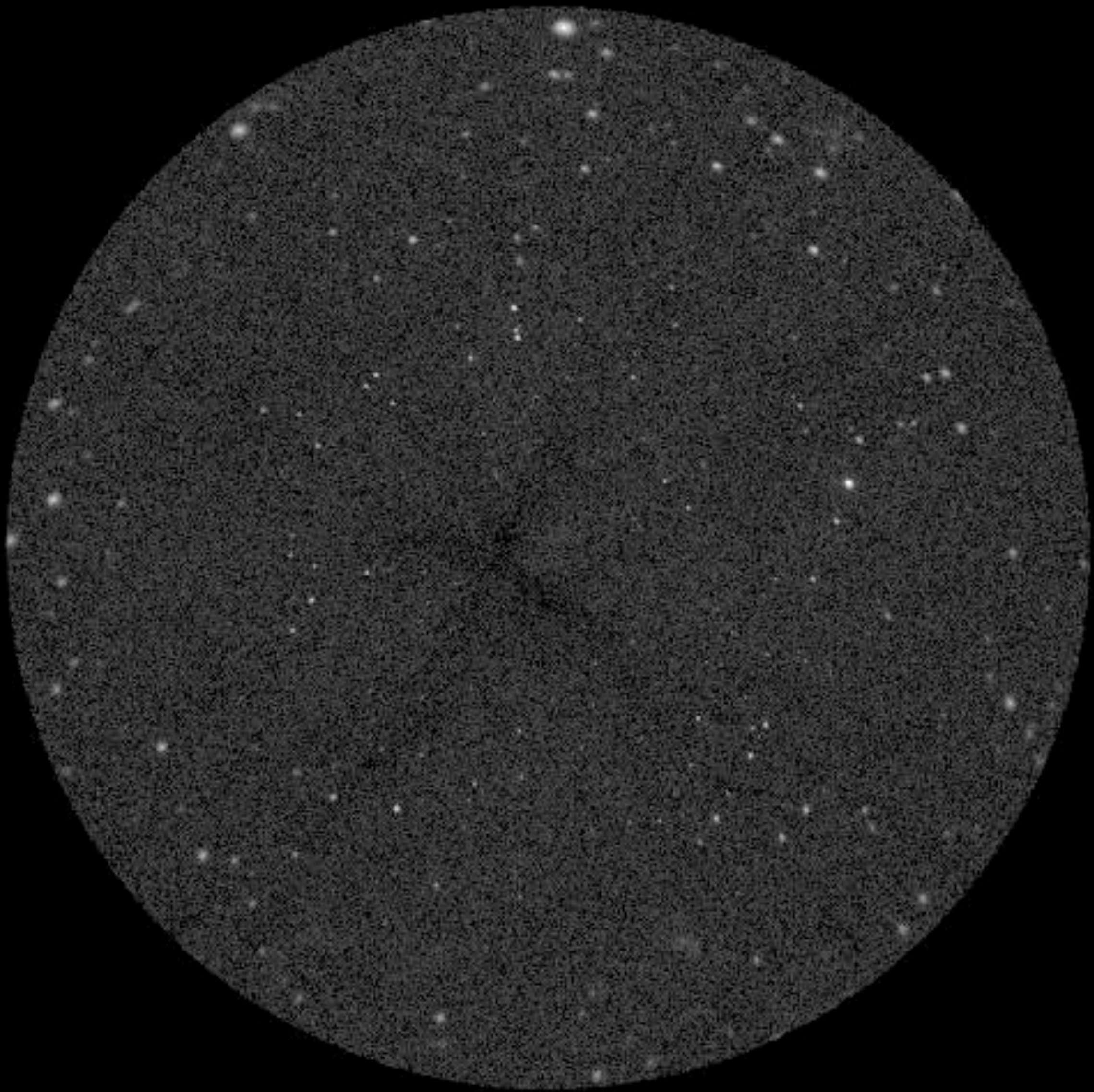
- Higher baseline SXRB level
- More variability
- Closer correlation of locally measured SW ion flux and SXRB level.



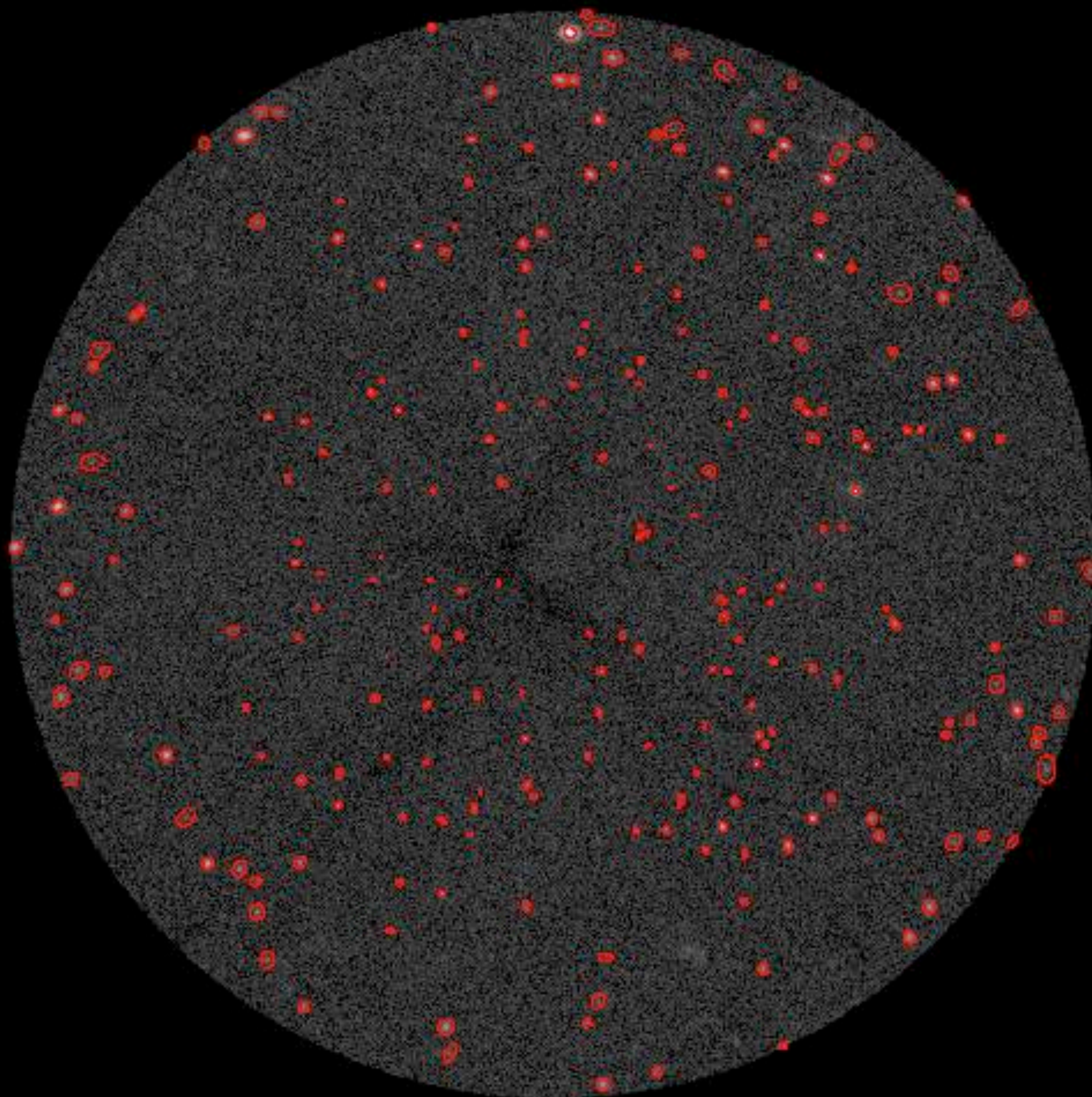
Data Analysis

Select field of view
common to all
21 observations



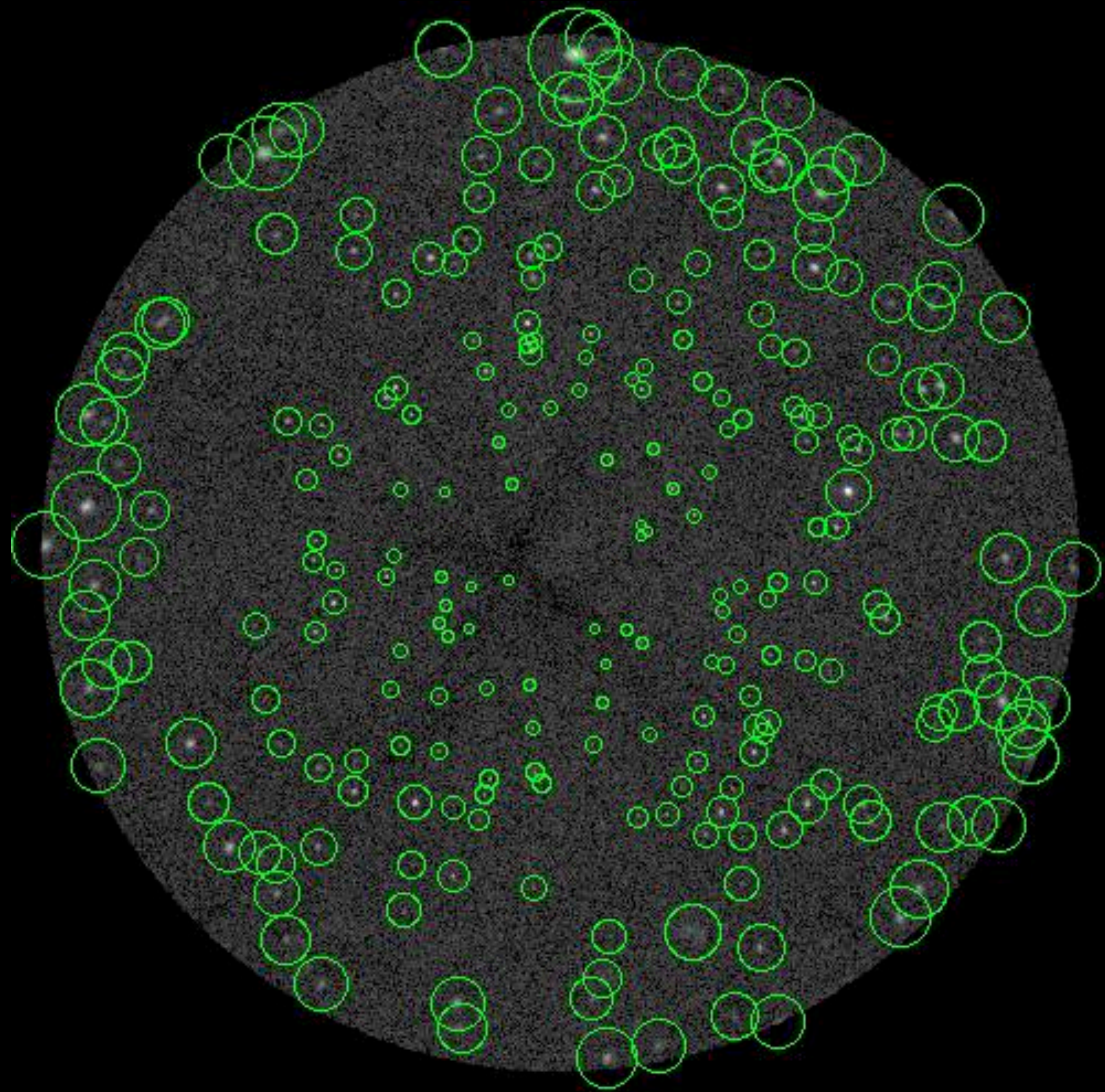


244 sources within 7.70 arcmin of aimpoint



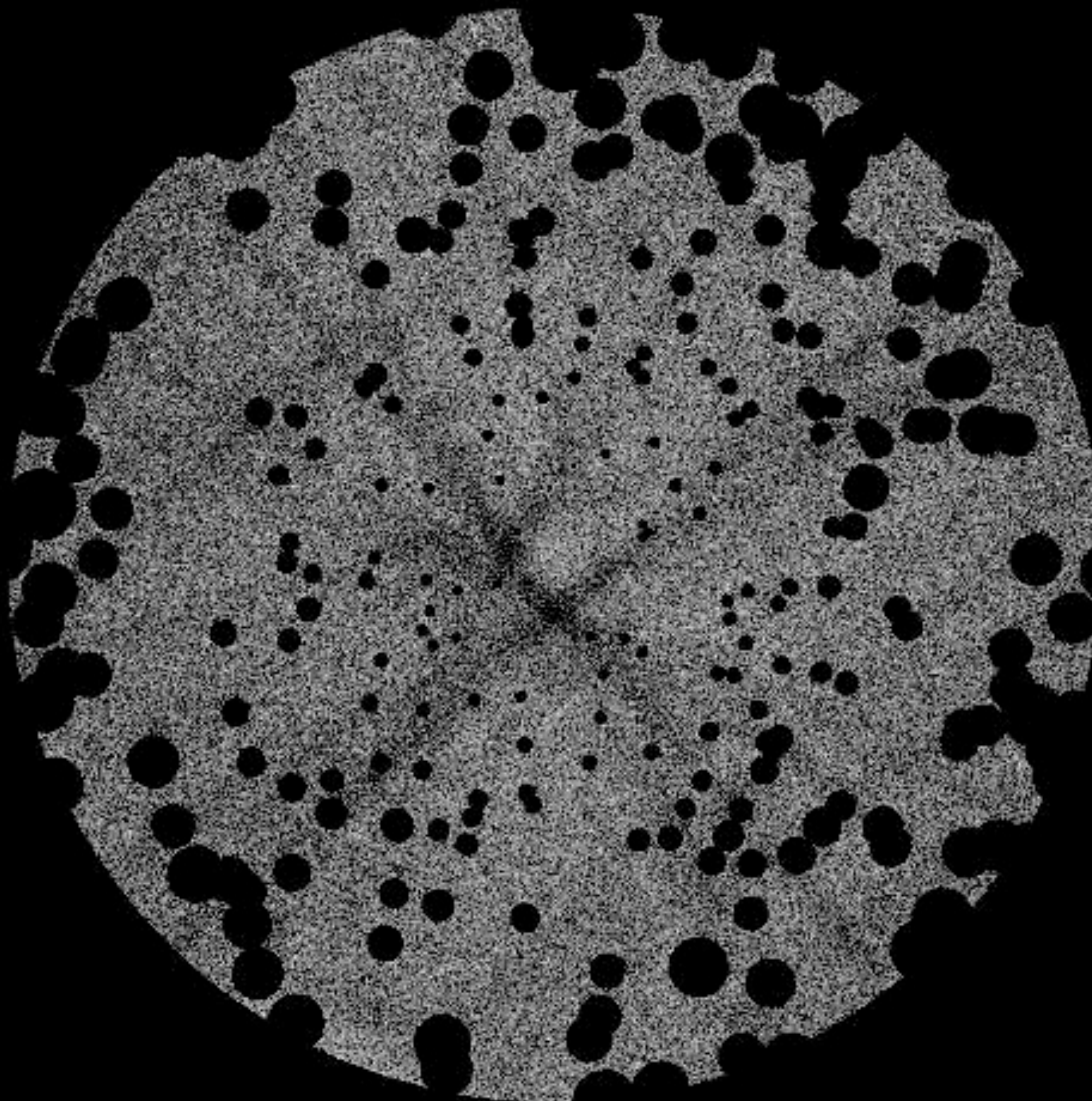
Remove 2 more diffuse sources, increase source region size to reduce source contamination to less than 2%.

Trim radius to 7.5'.

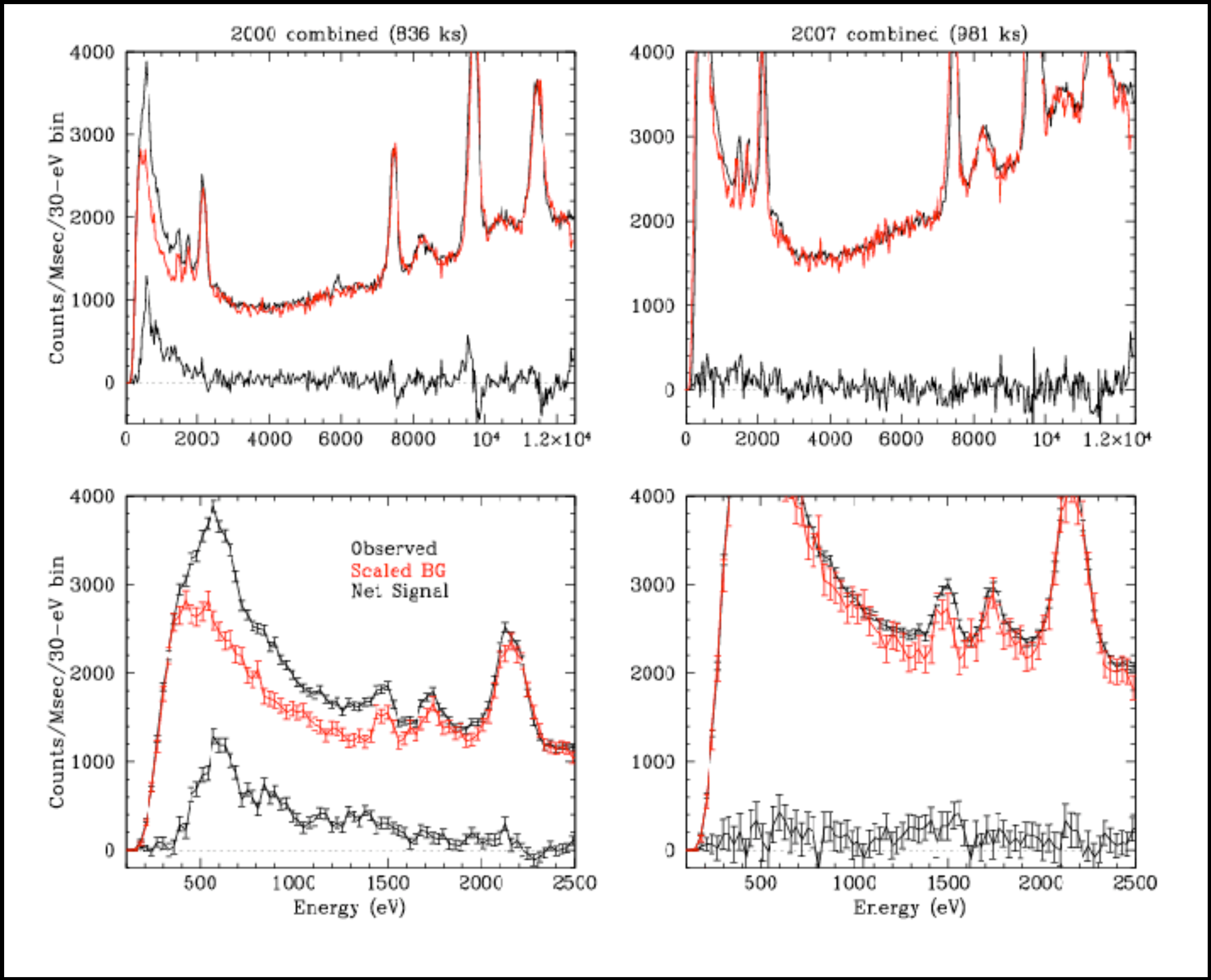


Remove periods with background flaring (less than 10 ks).

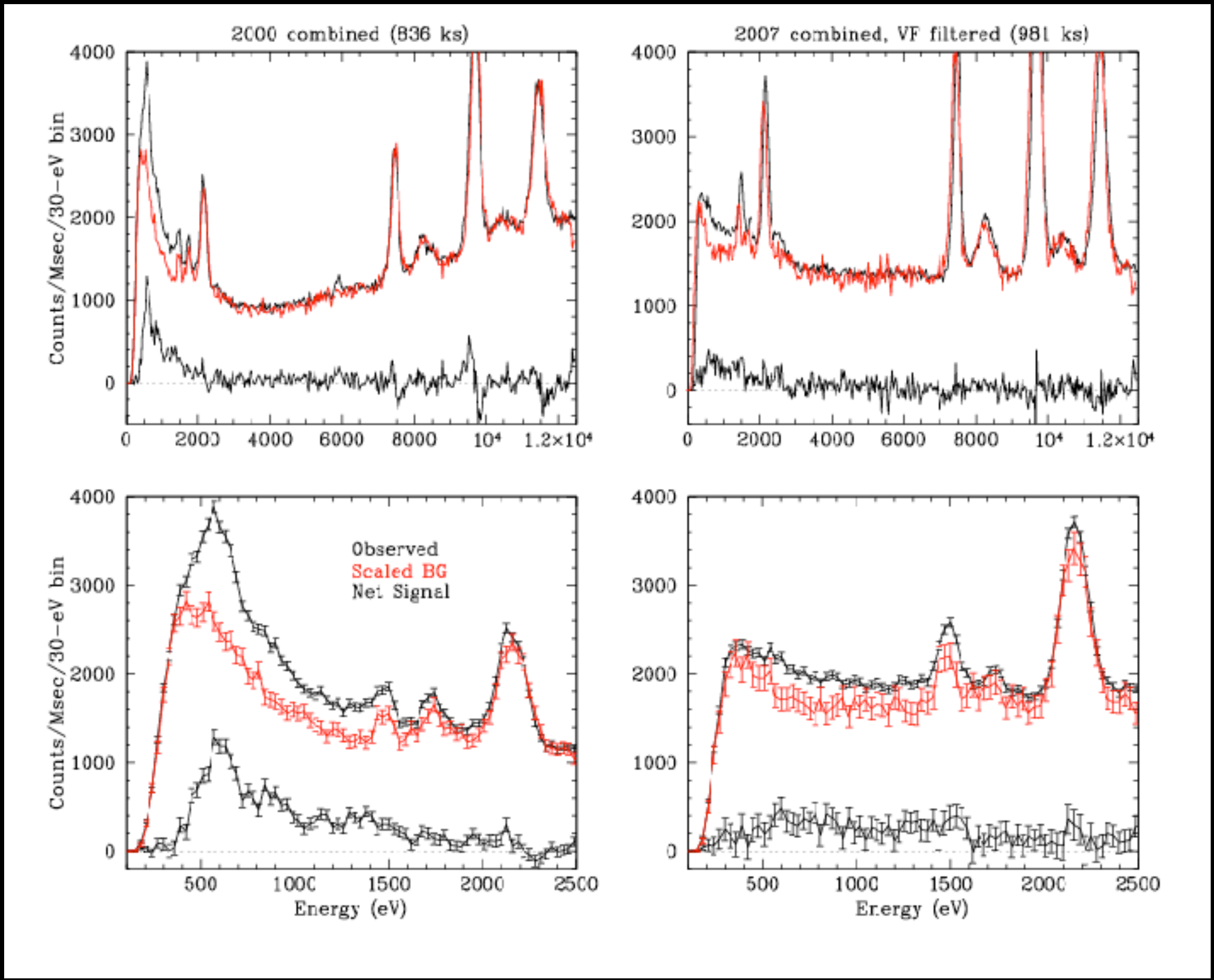
Quick comparison of summed 2000 data vs summed 2007 data ….



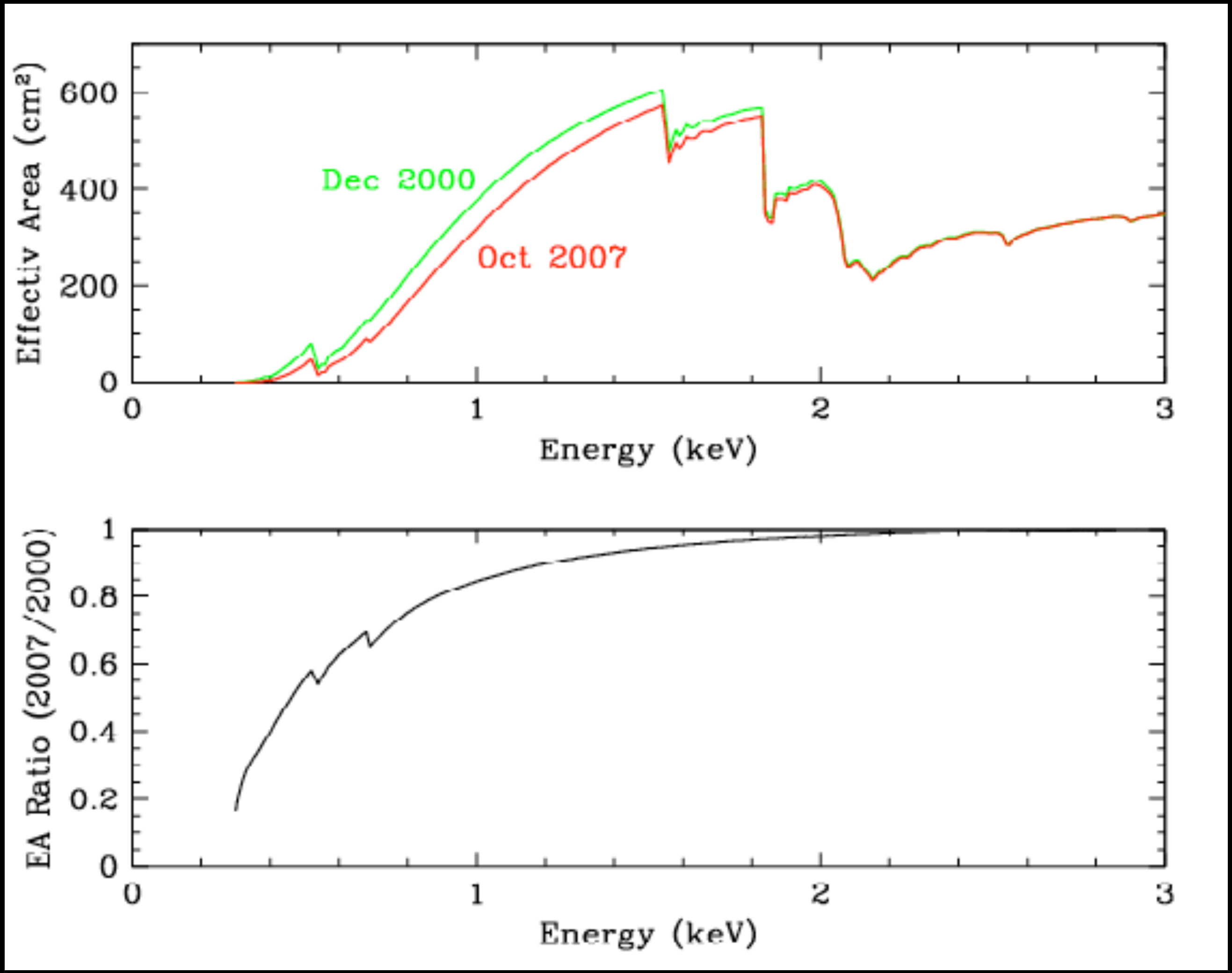
Detector BG 70% higher in 2007 than in 2000



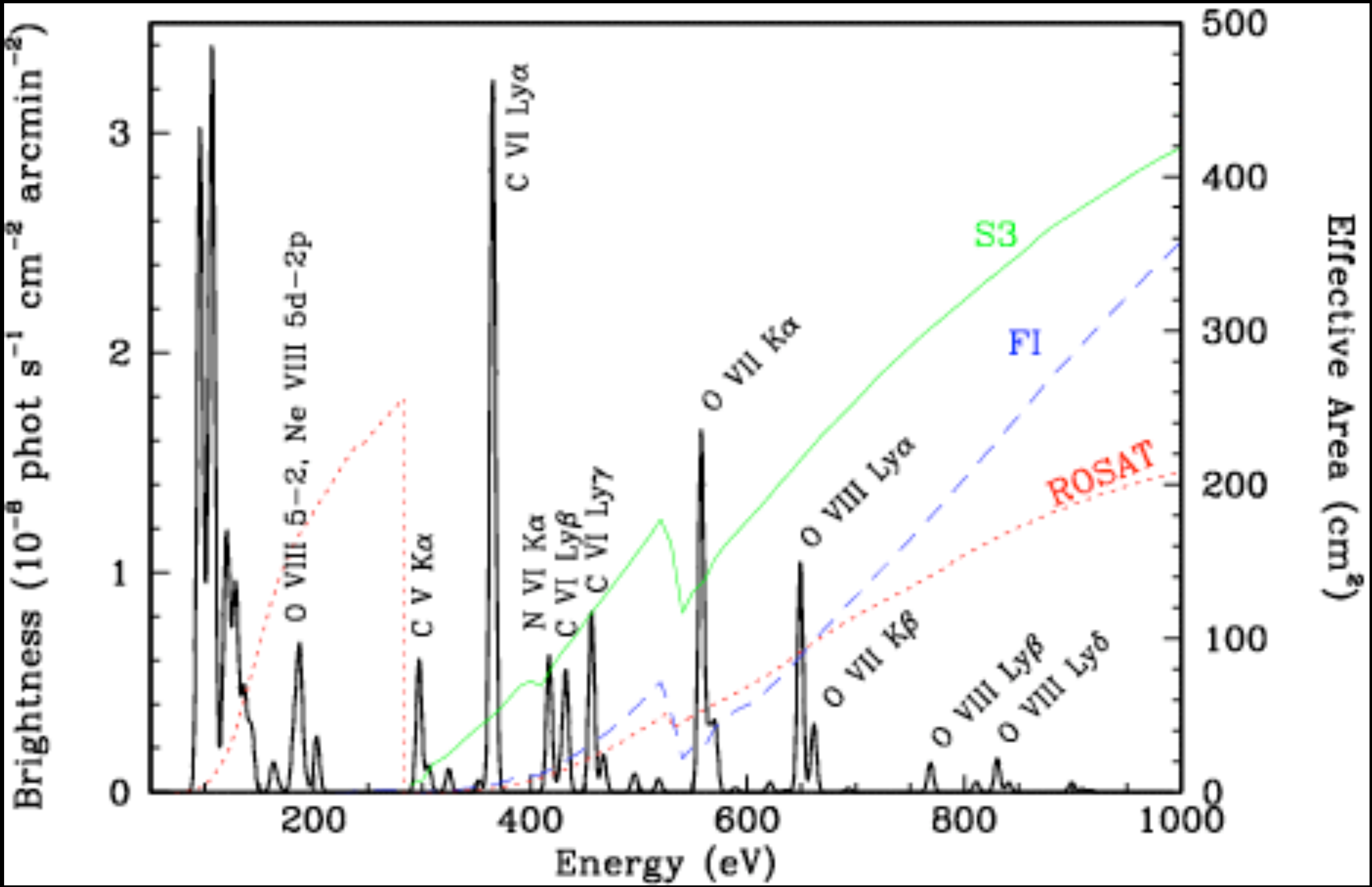
2007 observations in VF mode ⇒ filtering



Lower X-ray signal partly due to lower QE -- down by 40% at ~600 eV from 2000 to 2007.



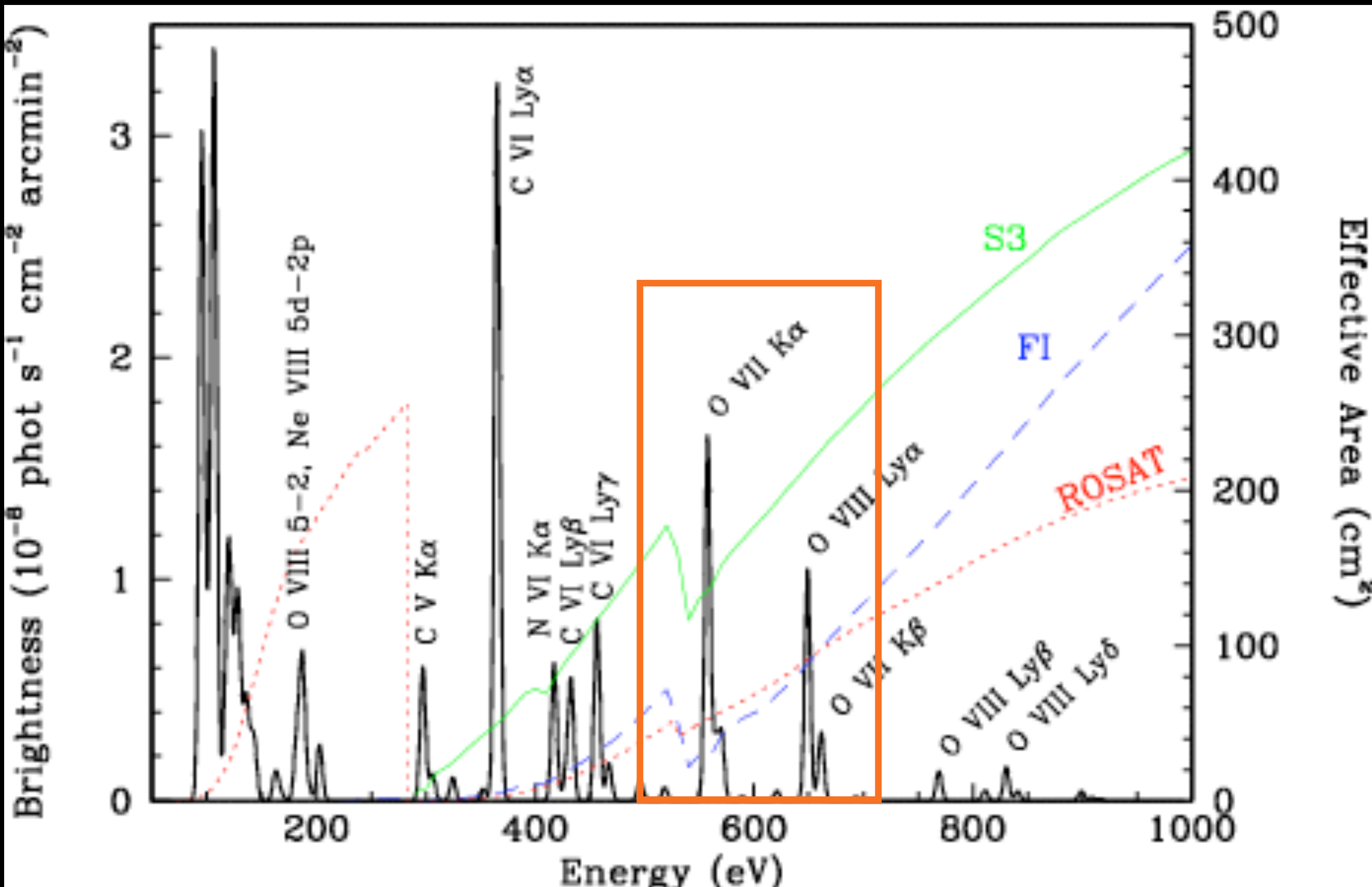
Compare O emission (520-710 eV) vs…



Model CX spectrum with 6 eV resolution

Wargelin et al., ApJ 2004

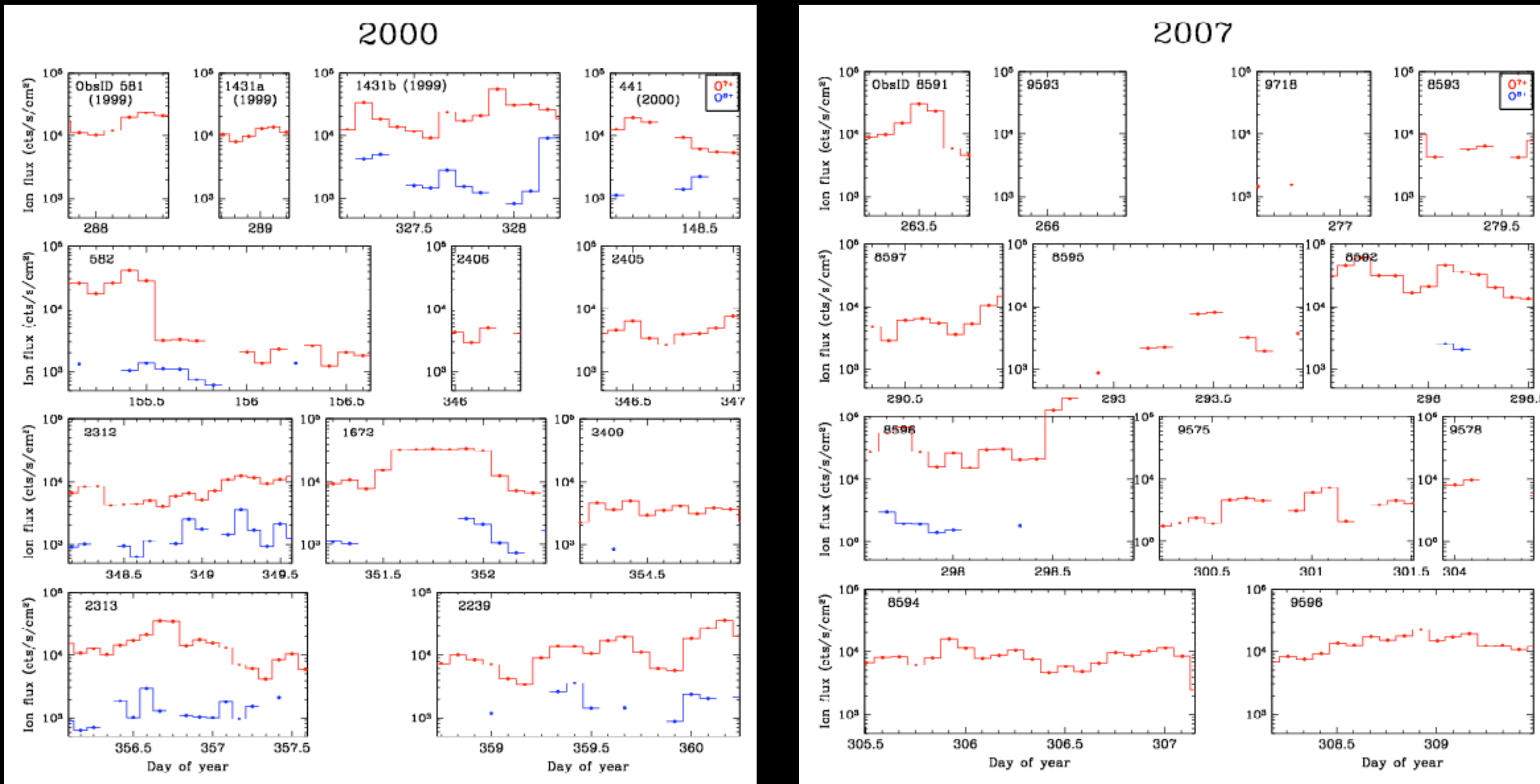
Compare O emission (520-710 eV) vs…



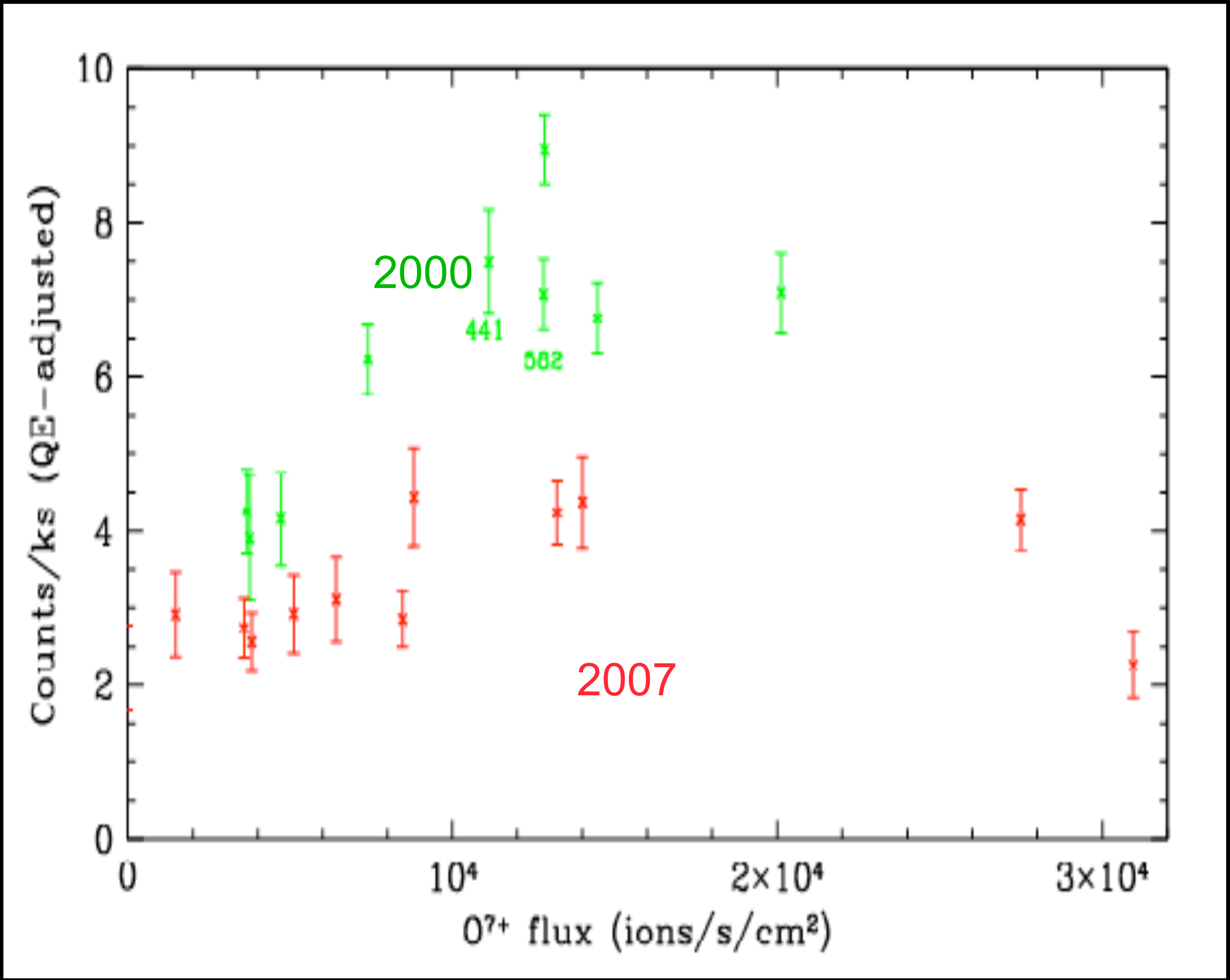
Model CX spectrum with 6 eV resolution

Wargelin et al., ApJ 2004

… average ACE/SWICS O^{7+} flux for each ObsID



Many thanks to the ACE/SWICS team for providing their public data!



Stronger CX and tighter X-ray/O7+ correlation in 2000--most emission from within He cone.

There may be no correlation with local SW flux depending on viewing geometry.

Did spectral fits for 3 lowest-rate obsids in 2000, lowest 8 in 2007. Convolved with ROSAT RMF.

R45 rates (in 10^{-6} cts/sec /arcmin^2):

54 in 2000

32 in 2007

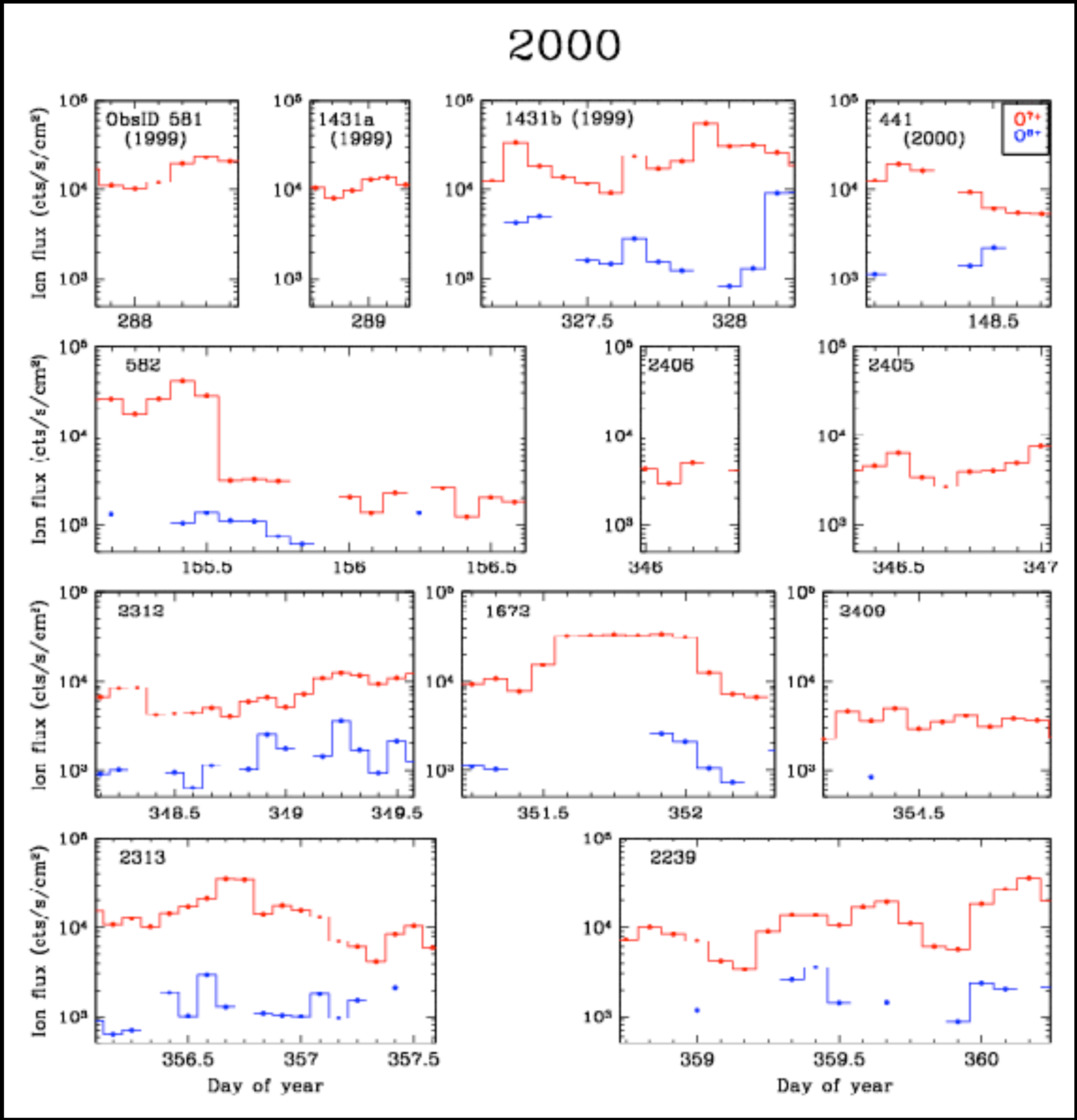
25 if no SWCX?

Talk amongst yourselves….

These are preliminary results. We will redo the analysis more carefully and completely, with painstaking spectral fits, comparisons with model predictions of heliospheric and geocoronal CX, etc, etc. etc.

Other things to think about:

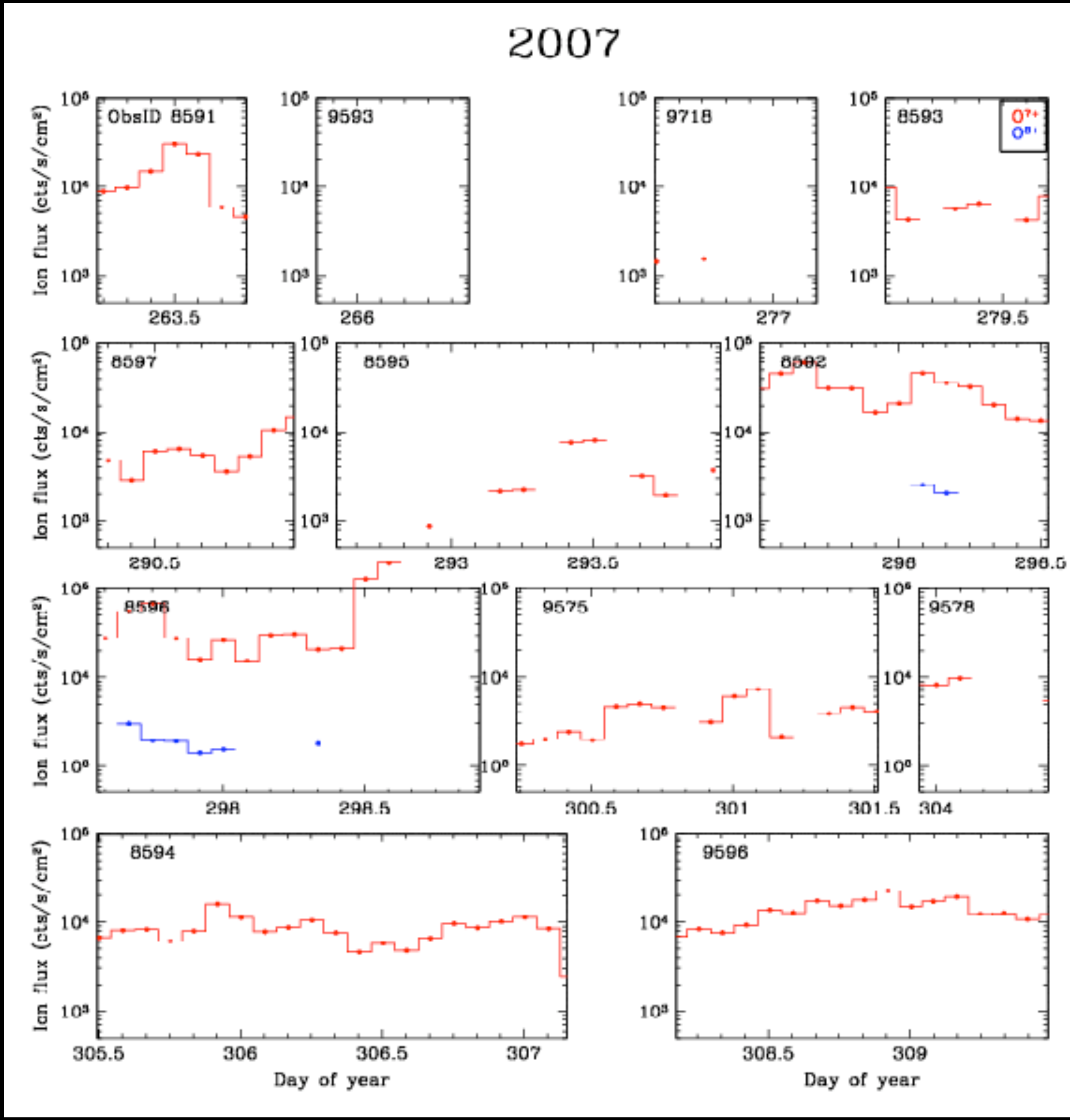
- Roughly 10% of RASS SXRB is from unresolved Galactic point sources
- RASS was conducted at solar max
- R12 (1/4-keV) rate ~4 x R45 (3/4-keV) rate
- LTEs most prominent in R12 band
- No models or data for CX in 1/4-keV band



More detailed correlations:

Short-term X-ray variability vs ACE O7+ flux ⇒ fractional contribution of geocoronal CX emission

Account for Chandra orbital geometry



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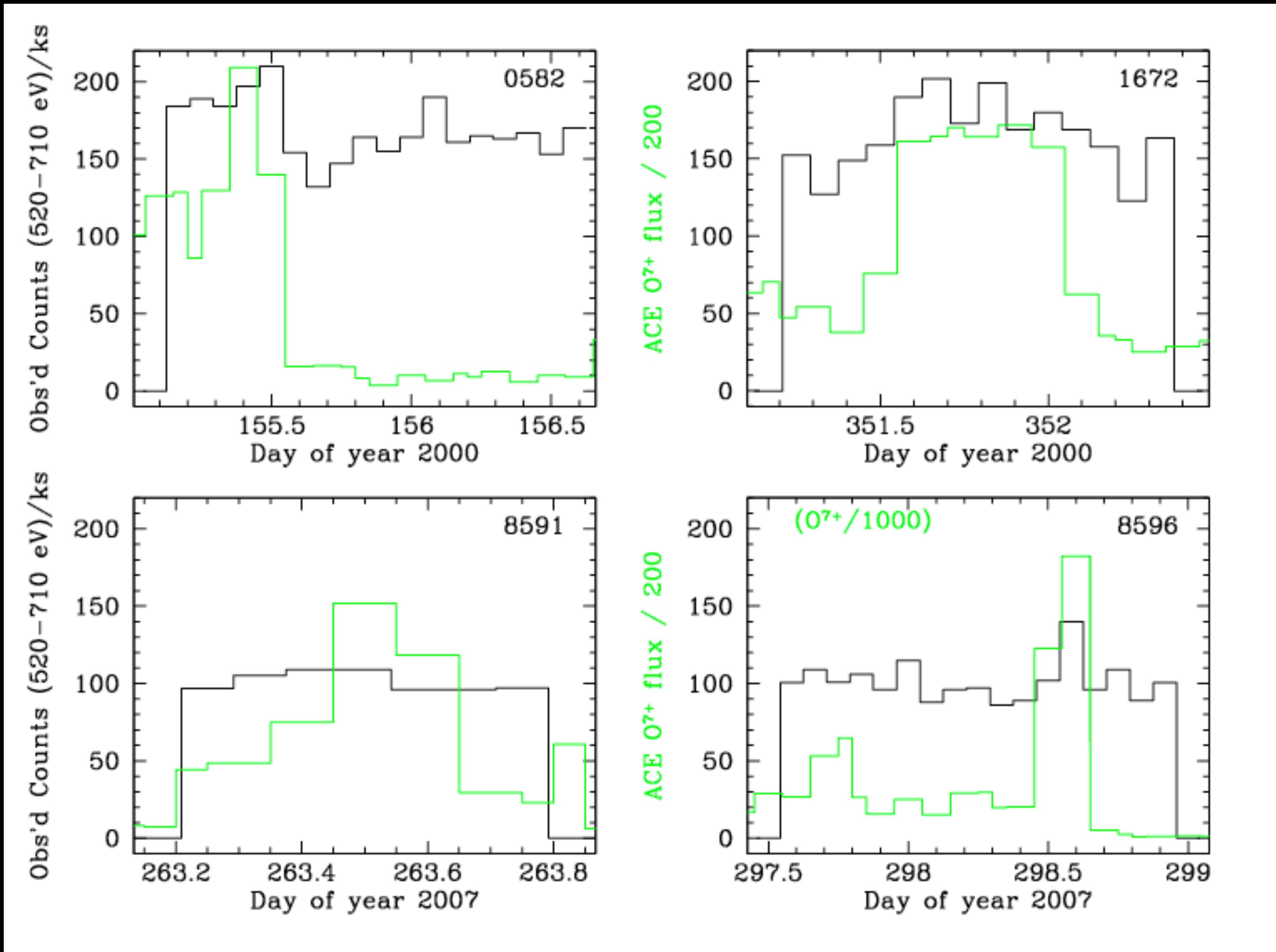
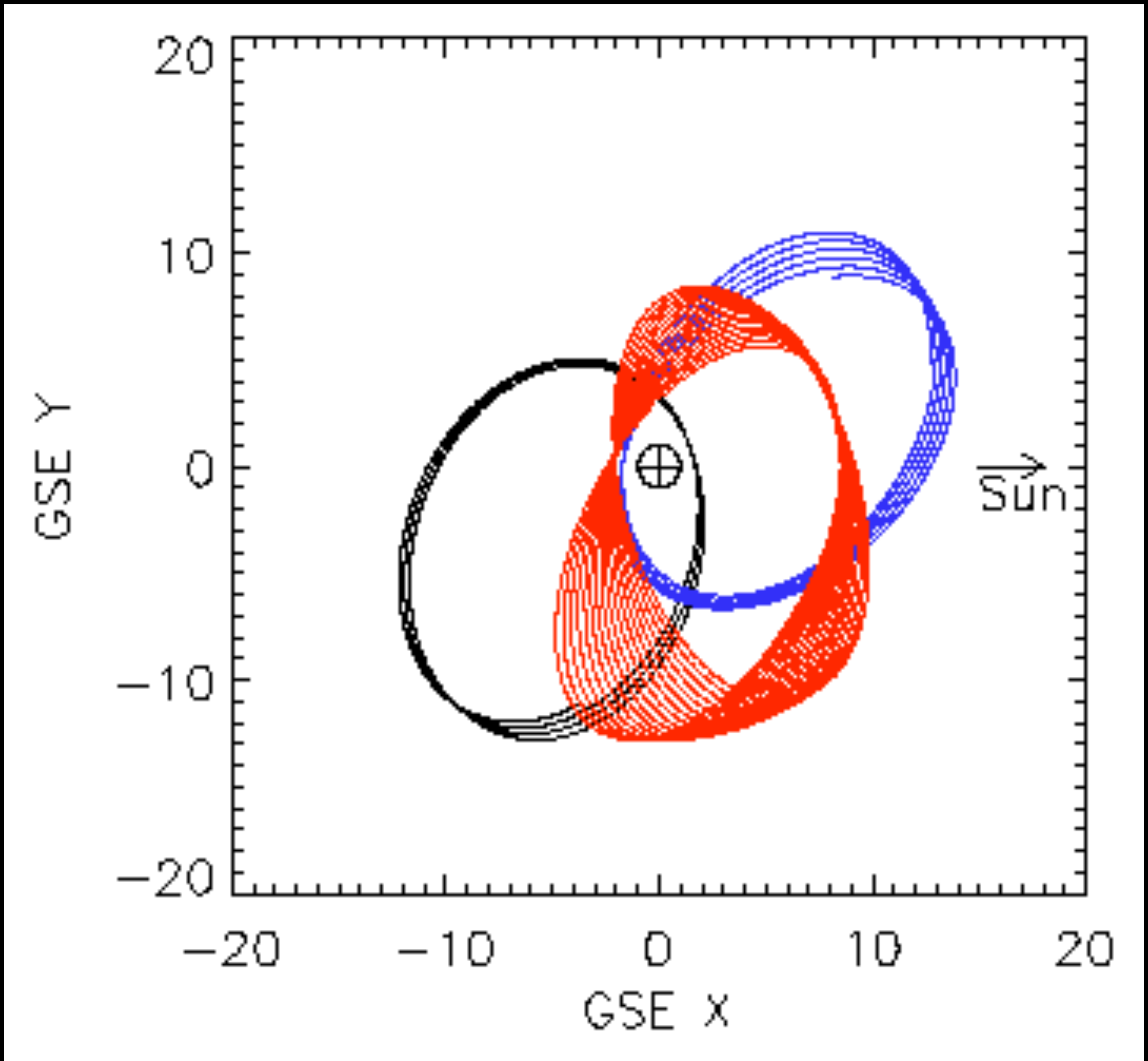
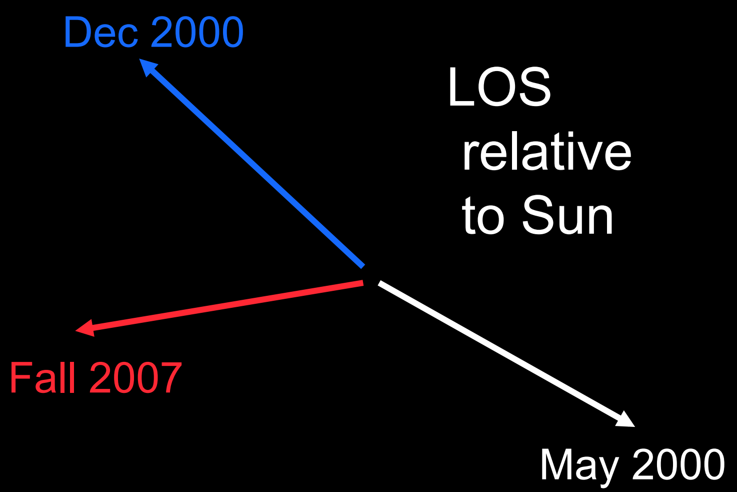


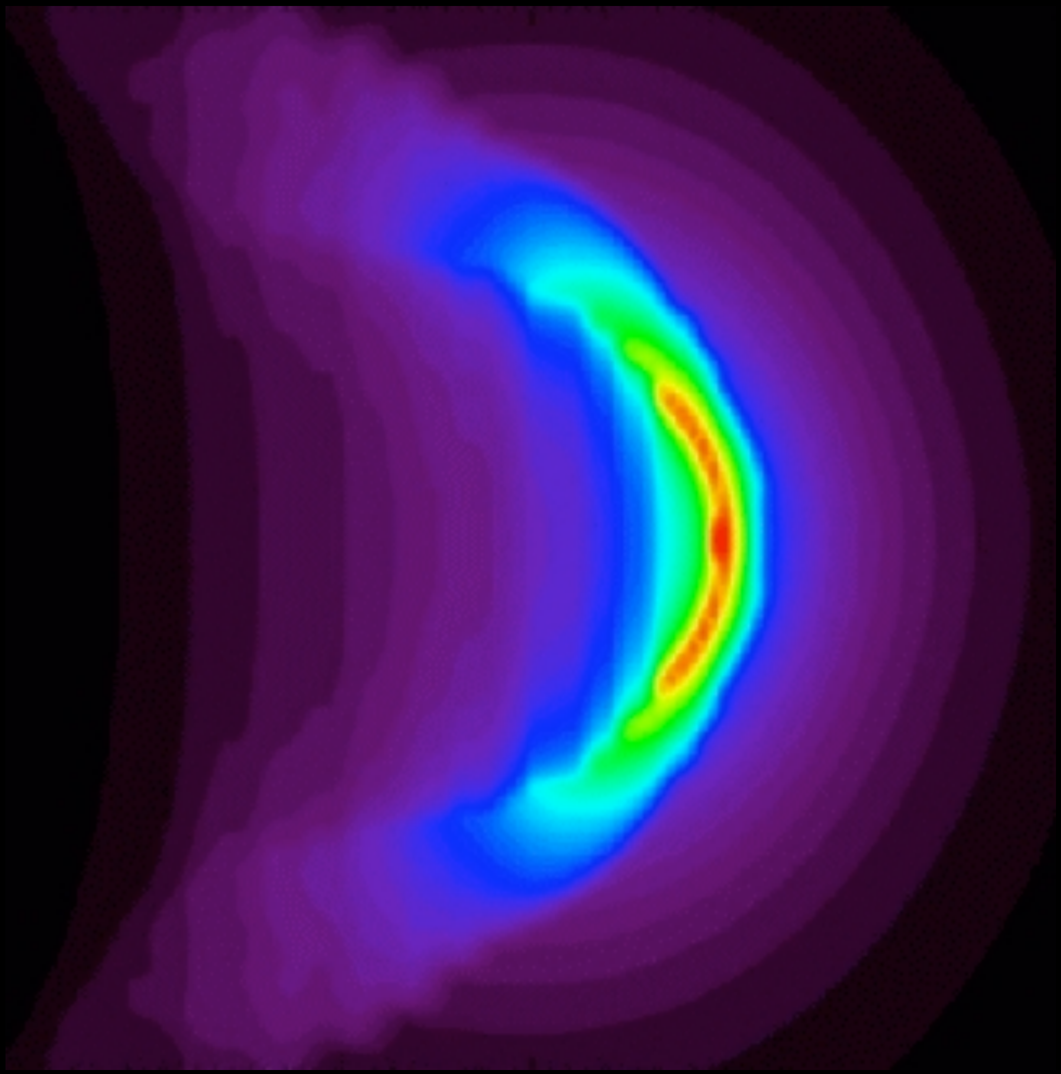
Geocoronal emission generally weaker than heliospheric but responds to SW ion flux much faster (because more local) and can sometimes be stronger.



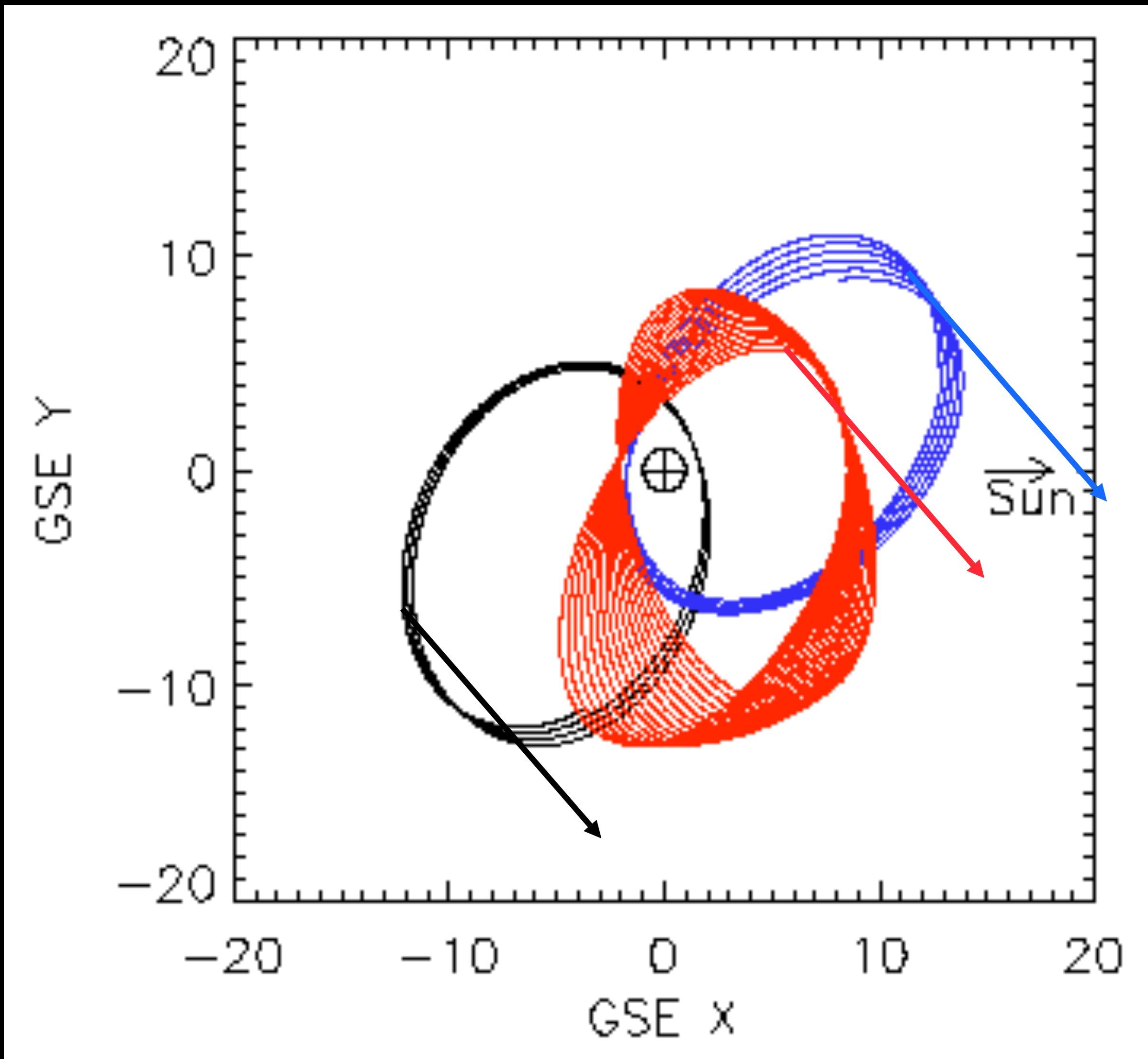


LOS relative to Sun

Account for effect of orbital viewing geometry on observed geocoronal emission.



Robertson et al., JGR (2006)



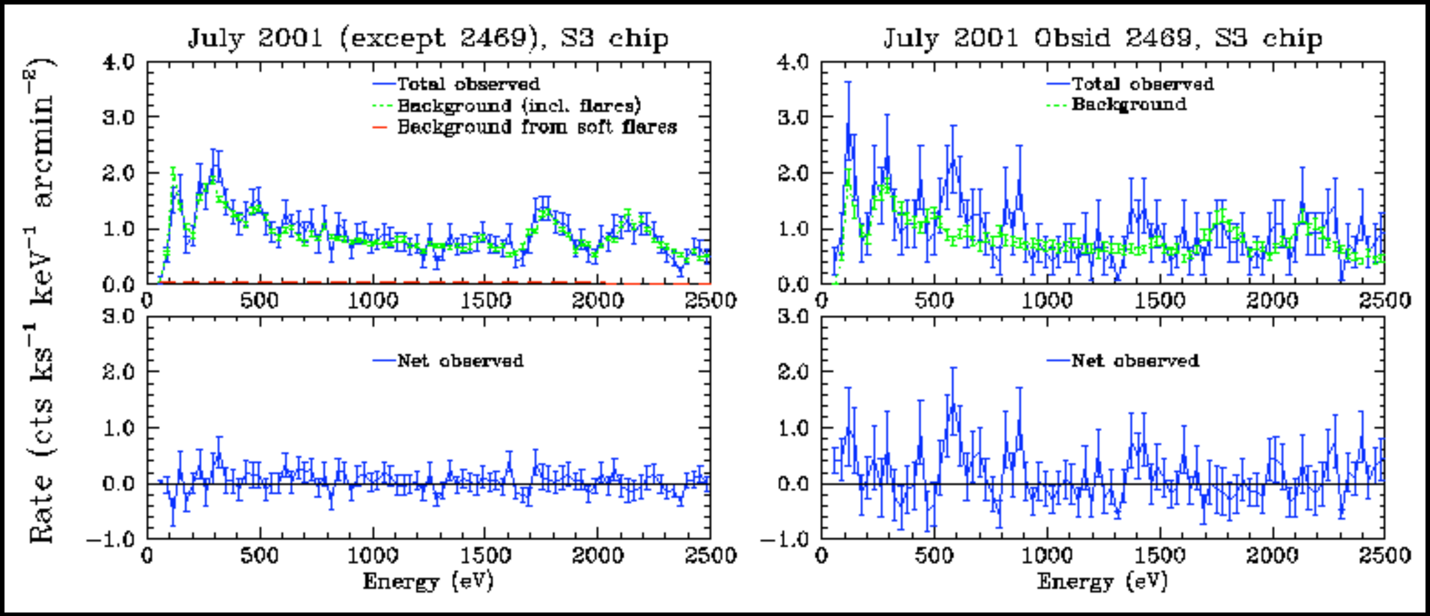
Compare simultaneous data from Chandra, XMM, Suzaku during SW “impulses.”

Modeling and observationally constraining SWCX is hard.

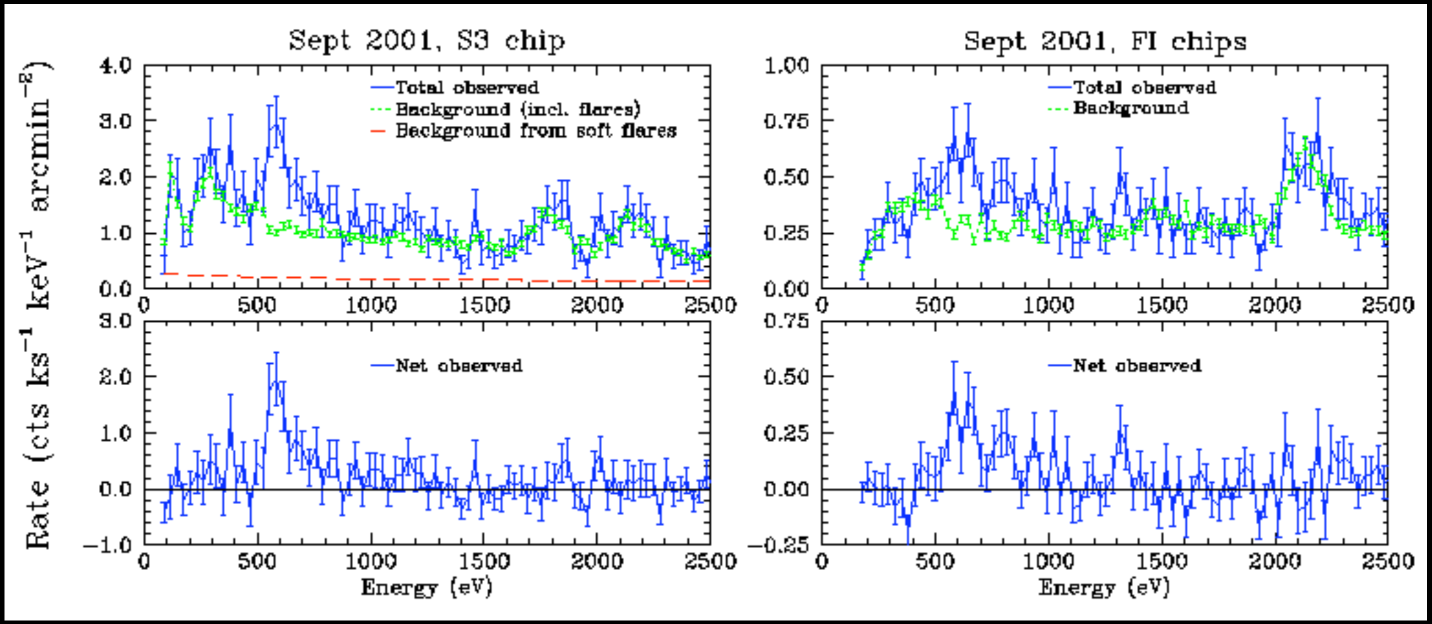
"The SWCX problem" will be solved when we have high-resolution spectra from microcalorimeters (ΔE=2-10 eV).

- CX spectra differ from collisional and we (will) know what they look like from lab work, strong LTEs, and He cone observations (coupled with SW velocity measurements). Use CX-enhanced lines (high-*n* Lyman, He-like *f*, etc.) to scale and remove CX emission templates from SXRB spectra.
- 400 km/sec $\Leftrightarrow$ ΔE~1 eV at 600 eV
- Can also operate in much of the 1/4-keV band

For more details on CX spectra and a primer on astrophysical X-ray CX emission, see Wargelin, Beiersdorfer, & Brown, "EBIT charge-exchange measurements and astrophysical applications," Canadian J. Physics, 86, 151 (2008).



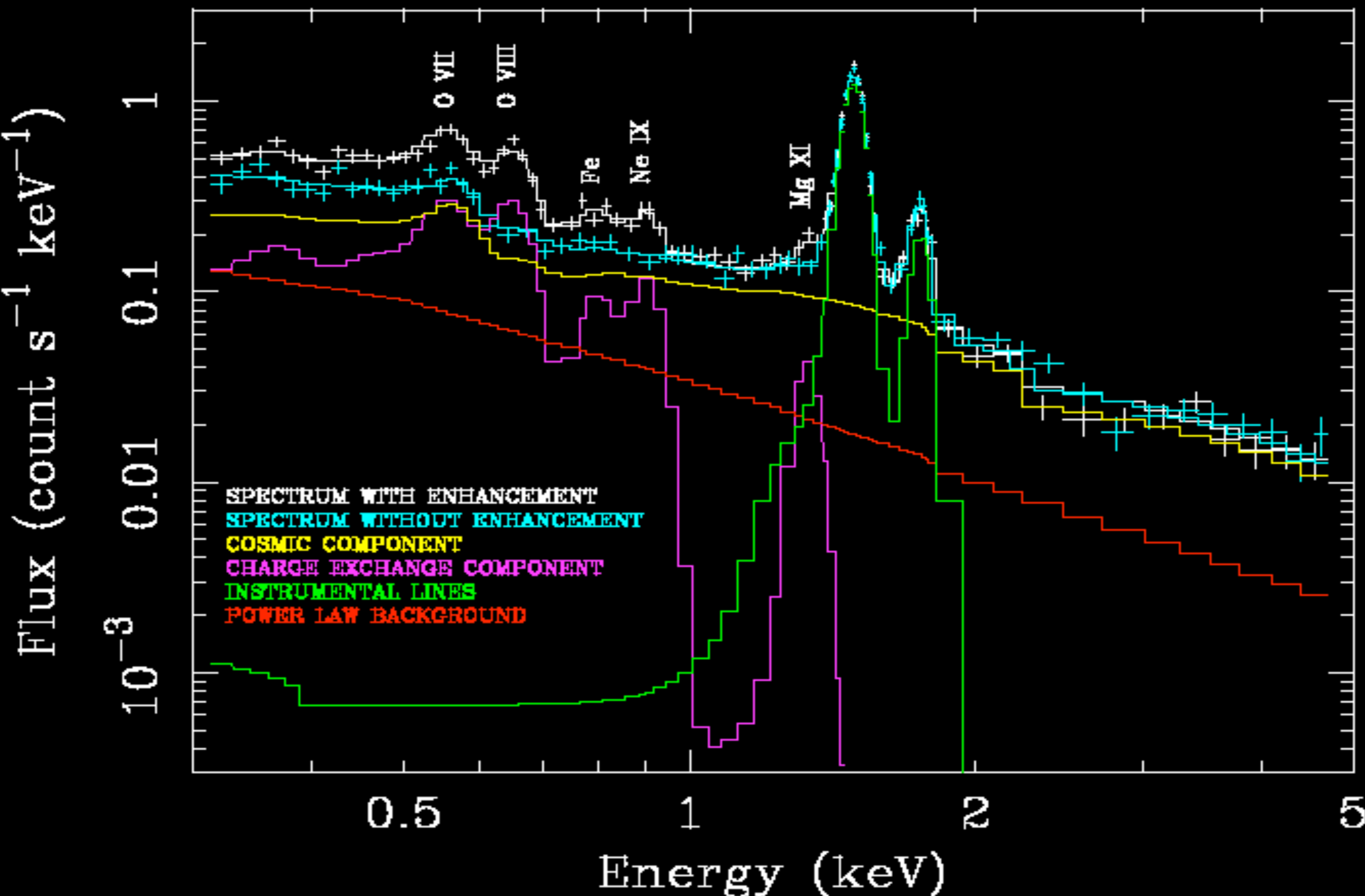
July 2001 (except 2469), S3 chip
July 2001 Obsid 2469, S3 chip
Total observed
Background (incl. flares)
Background from soft flares
Background
Net observed
Rate (cts ks^{-1} keV^{-1} arcmin^{-2})
Energy (eV)



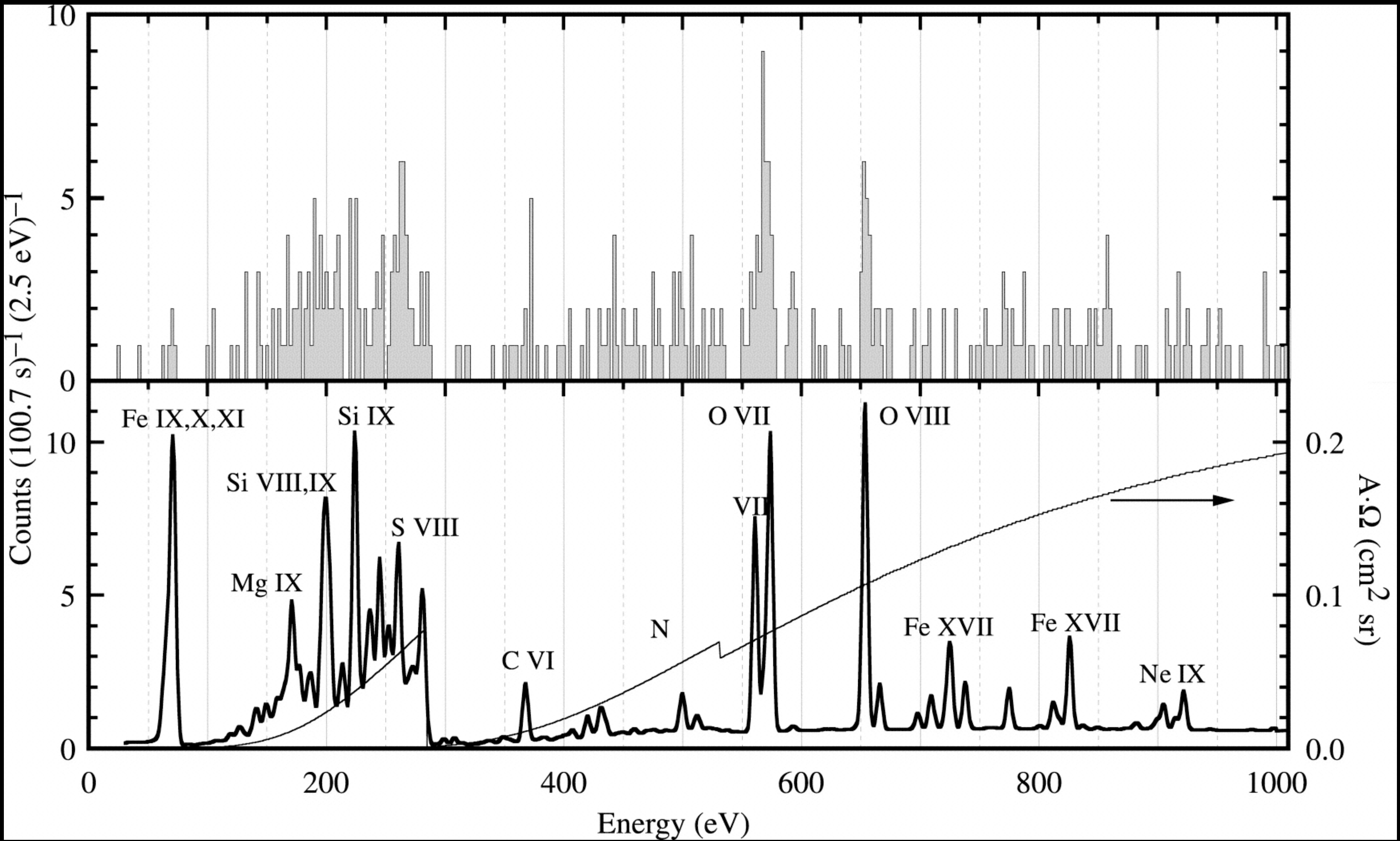
Sept 2001, S3 chip
Sept 2001, FI chips
Total observed
Background (incl. flares)
Background from soft flares
Background
Net observed
Rate (cts ks^{-1} keV^{-1} arcmin^{-2})
Energy (eV)

CXC

XMM HDF-N. Snowden et al, ApJ (2004)

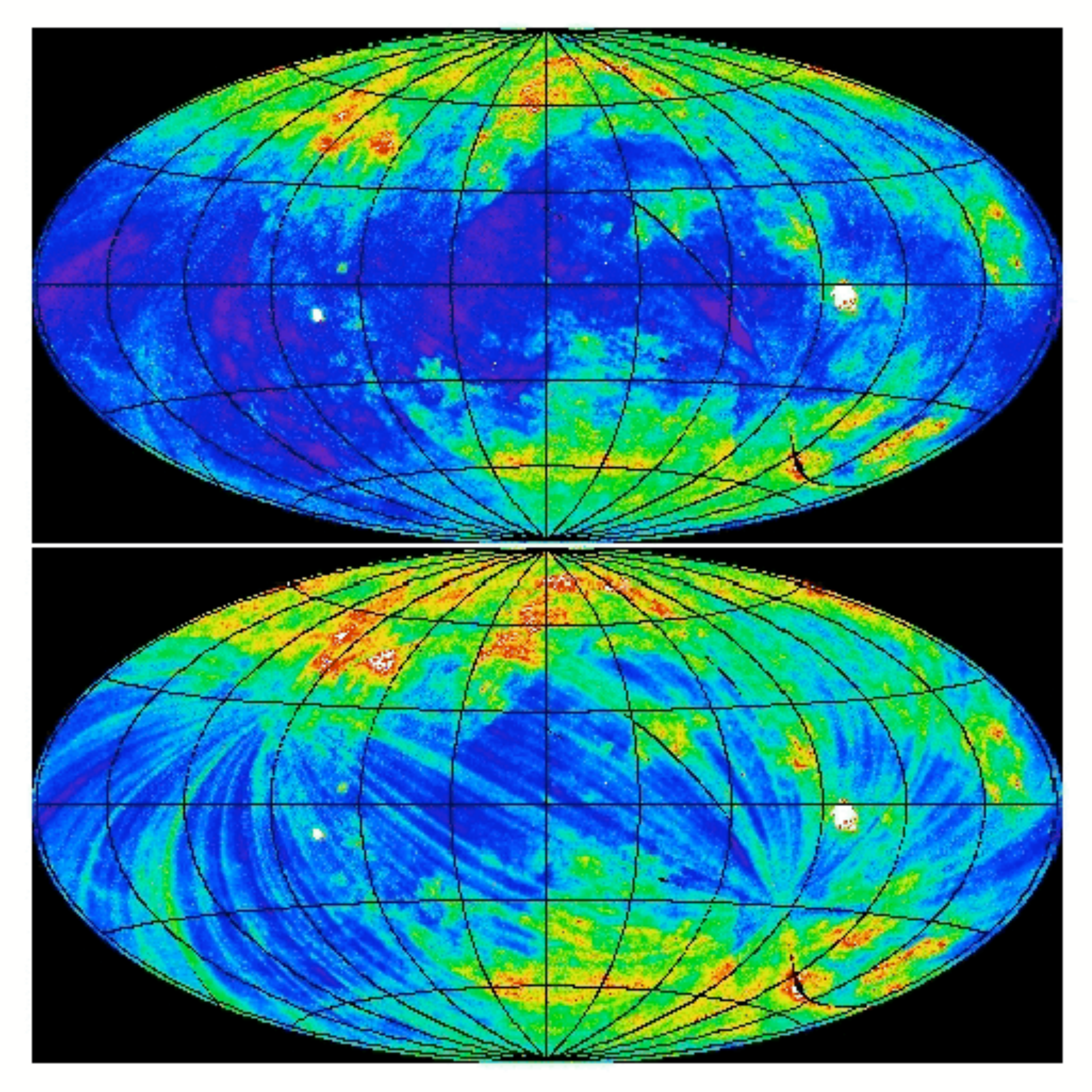


X-Ray Quantum Calorimeter (XQC)



100s of SXRB from rocket flight. McCammon et al (2004?)

ROSAT All-Sky Survey Map (R12) and LTEs



Long Term Enhancements from geo/helio CX fluctuations.

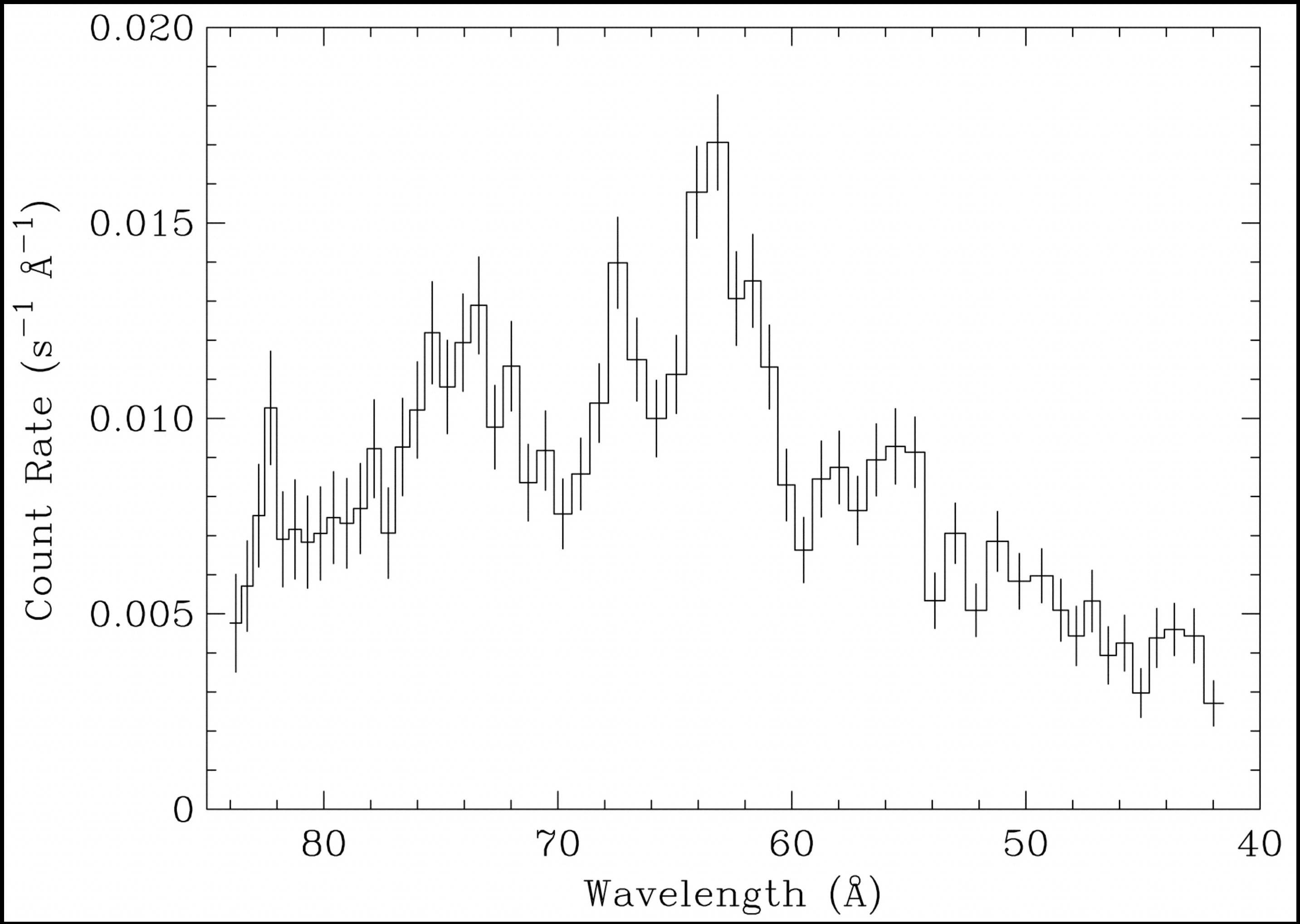
Strongest in R12 band.

Current CX models known to be incomplete (no L-shell Mg, Si, S, Fe).

Some hints in current data.

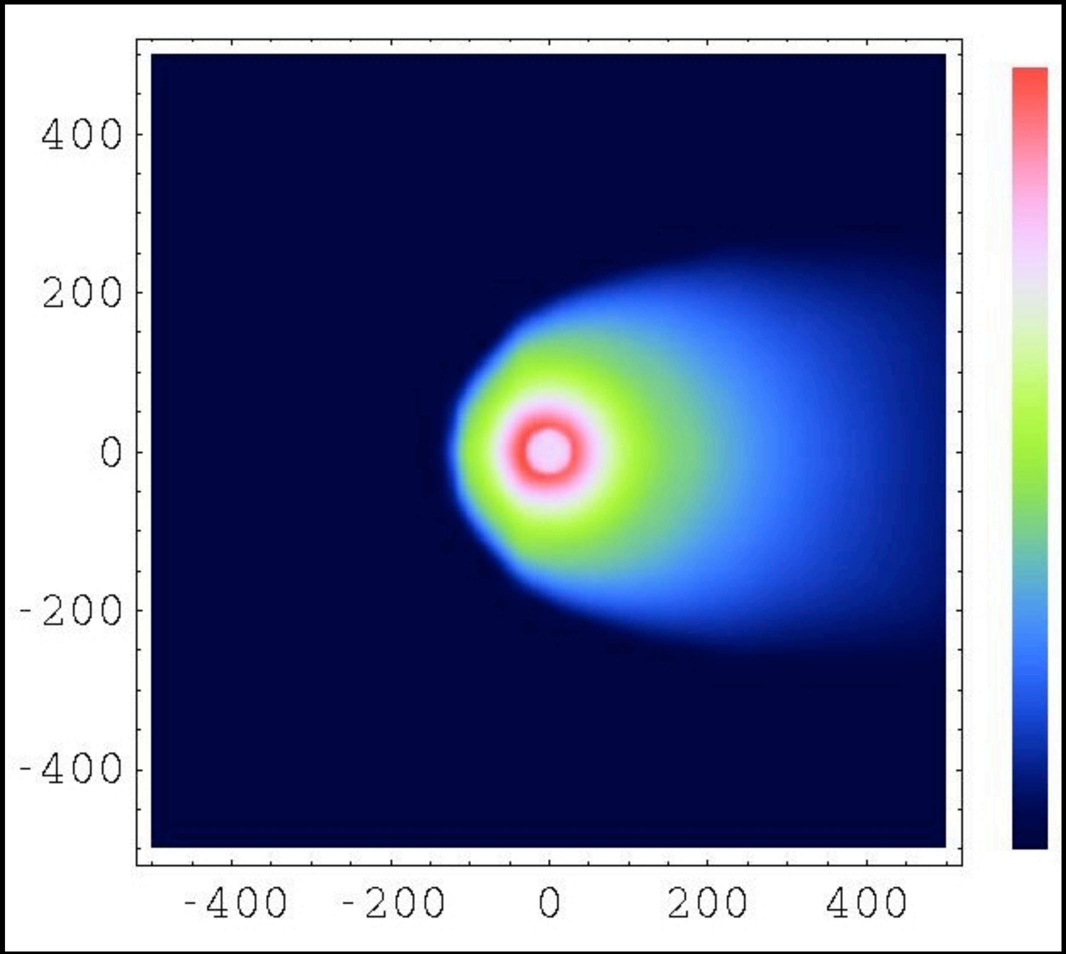
S. Snowden

Diffuse X-Ray Spectrometer (DXS)



SXRB 150-300 eV. Sanders et al. (2004?)

Heliospheric Charge Exchange



Solar wind + H/He from ISM → 100-AU halo.

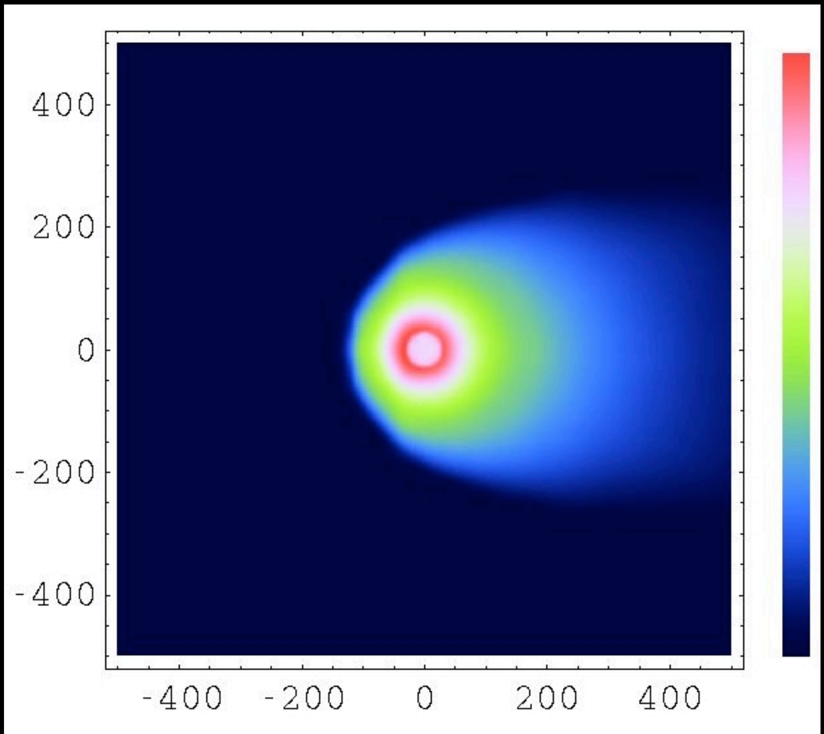
Intensity varies with look direction and solar activity.

Heliospheric CX ~ 10x geocoronal CX

Geo+Helio CX contributes 5-50^{+}% of SXRB, with major implications for models of LISM/Local Bubble.

Model heliospheric CX emission. Axis units in AU. LIC is moving to the right. Robertson et al. AIP Proc. 719 (2004).

Astrospheric Charge Exchange



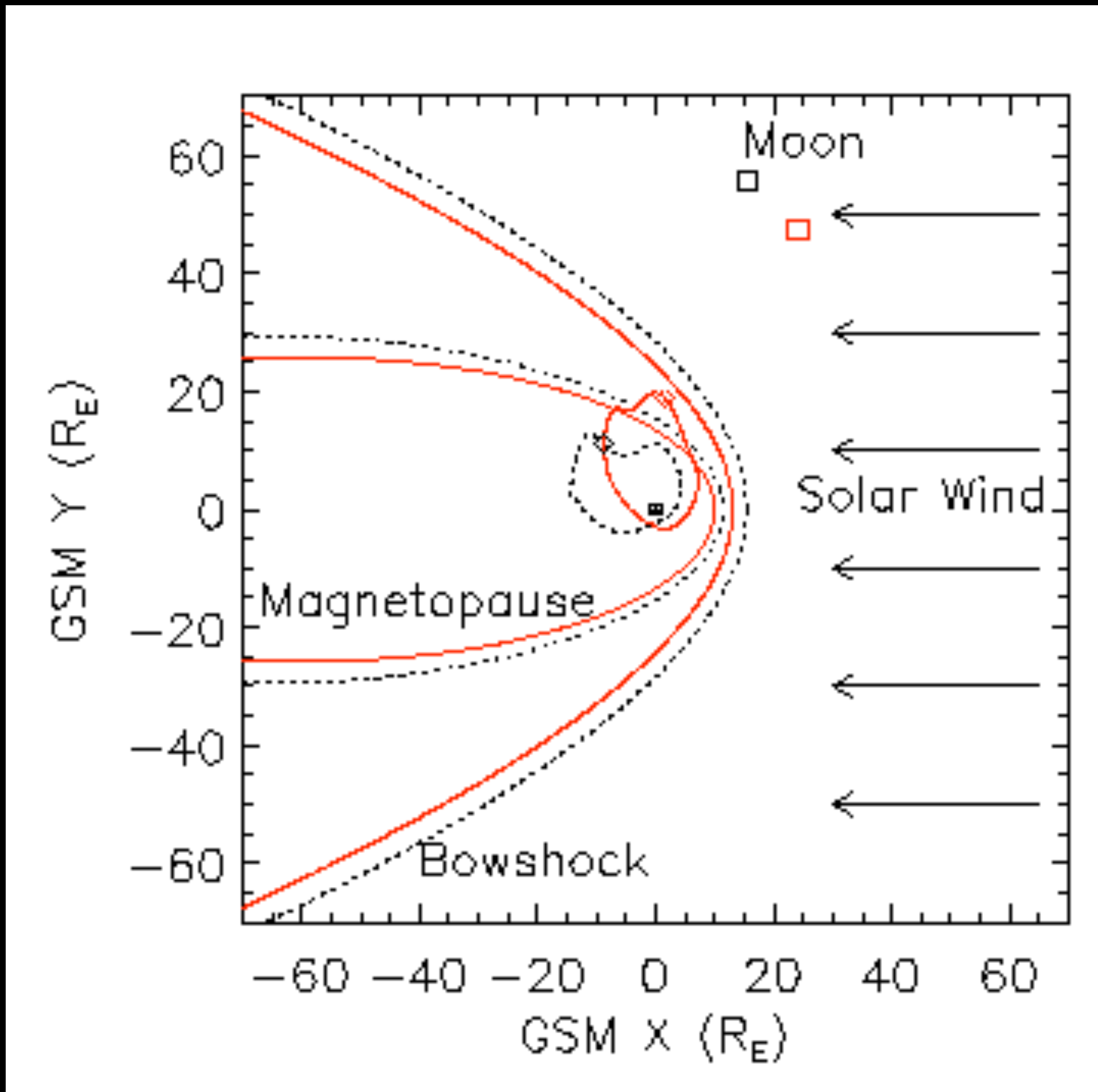
CX must also occur around other stars with highly ionized winds (G,K,M) residing inside clouds with neutral gas (LIC, G).

Imaging + spectra yields:

- Mass-loss rate
- Local $n_{neutral}$
- Wind velocity and composition
- Astrosphere geometry

CX emission weak, coronal emission ~10^4x brighter.

Need very large collecting area, good spatial and spectra res---not quite doable yet…


Moon
Solar Wind
Magnetopause
Bowshock
60
40
20
0
−20
−40
−60
GSM Y (R_E)
−60 −40 −20 0 20 40 60
GSM X (R_E)